PHARMACEUTICAL SUBSIDISATION IN NEW ZEALAND: A COMPARISON OF REFERENCE PRICING WITH THE JOHNSTON-ZECKHAUSER SCHEME

A thesis

submitted in partial fulfilment

of the requirements for the Degree

of

Master of Arts in Economics

in the

University of Canterbury

by

R.P. Edlin

University of Canterbury

1998

14
2
3
8

CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

An alternative scheme has been suggested to the reference pricing framework currently used in New Zealand. The subsidisation scheme outlined in Johnston, M and Zeckhauser, R. (1991) *The Australian Pharmaceutical Subsidy Gambit: Transmuting Deadweight Loss and Oligopoly Rents to Consumer Surplus* offers only the subsidy required to prompt acceptance of subsidisation by firms. This scheme is valid only where marginal costs are known. This thesis incorporates the creation of a framework for the comparison of pharmaceutical subsidy schemes, the expansion of the Johnston and Zeckhauser scheme into an environment of imperfect information, and the comparison of this modified scheme with the variant of reference pricing used in New Zealand.

This comparison finds that the Johnston and Zeckhauser scheme generally provides subsidisation at a lower cost than reference pricing provided that a suitable threshold is placed on the time taken for a firm to accept subsidisation. Unfortunately the JZ scheme does not appear to provide a valid alternative to reference pricing as, on average, it is likely to promote a lower level of efficiency than the status quo. The thesis finds that reference pricing is however not without its problems, as the possibility exists that reference pricing will, in some cases, provide firms with less than the level of profit necessary to convince them to accept subsidisation.

CHAPTER 1

INTRODUCTION AND AIMS

Pharmac was set up in 1993 in New Zealand to decide which medicines and related products receive subsidies. Pharmac, on page 6 of *PHARMAC: the first 20 months,* states that it seeks to incorporate "a balanced view of the needs of both prescribers and patients. Decisions aim to achieve long term gains and efficient ways of supplying pharmaceuticals to the community."

Pharmac's aim is to ensure that there is fair and equitable patient access to medicines which contribute to New Zealander's health, through vigorous assessment of medicines and the effective management of public subsidies for them.[1]

Pharmac cannot provide what it cannot afford. If Pharmac is to provide the highest level of quality medication it can with the notional budget at its disposal it must use the scheme providing predictable subsidisation at the lowest cost. This thesis attempts to compare reference pricing with an alternative scheme suggested by Johnston, M and Zeckhauser, R. (1991) *The Australian Pharmaceutical Subsidy Gambit: Transmuting Deadweight Loss and Oligopoly Rents to Consumer Surplus.* This alternative scheme attempts to use the strategic advantage of the subsidising agency to the benefit of both the patient and the taxpayer.

The first task undertaken in this thesis is the creation of a framework for consumer choice. This framework will then be used to compare reference pricing with the Johnston and Zeckhauser (JZ) scheme referred to above. This scheme uses cost information to offer firms only that subsidy required to prompt acceptance of the offer. The schemes will first be compared under perfect information. The major results of this thesis are expected in the second comparison however where marginal costs must be revealed before subsidisation can take place. The delay that cost revelation requires may make reference pricing superior in the more realistic case where marginal costs are initially unknown. Finally, it is hoped that a recommendation can be made as to whether the JZ scheme is worth exploring further in the New Zealand context.

---

[1] http://www.pharmac.govt.nz/page_2.htm.

CHAPTER 2

A MODEL OF PATIENT CHOICE

A framework for patient choice must be formulated before any analysis of the market for pharmaceuticals and subsequent analysis of pharmaceutical subsidisation can occur. The aim of this chapter is to compose such a model of patient behaviour where, given the price and overall quality of different drugs (in addition to the estimation of doctors about these qualities), the quantity of each drug consumed can be determined. This quantity shall be independent of time except where time affects the values of price, quality and the doctor's estimation of quality.

The consumption of pharmaceuticals contains inherent risk because no patient can be sure of their reaction to a specific drug.[1] Any model of patient behaviour concerned with drug consumption must carefully consider this risk. Superior quality drugs involve either lower uncertainty in outcome for consumers or, alternatively, a greater efficacy to compensate for an increased risk of suffering a serious side effect. Section I contains a framework for dealing with drug quality while Section II addresses the relationship between doctors and patients. Section III addresses the method patients use to discover the quality of different drugs while Section IV discusses the method used to choose between drugs once some drug qualities are known. Finally, Sections V to VII discuss expected utility, intertemporal concerns and, finally, outline the quantities of different drugs chosen.

[1] Before either a pre-treatment test of the drug or treatment using the drug.

I. DRUG QUALITY AND DIMENSIONS

The multi-dimensional facets of drug quality make complete dominance of one drug over another unlikely. Pharmac identifies the following criteria in its operating policies as pertinent pharmacological and therapeutic information required when applying for listing on the pharmaceutical schedule:[2]

(i) Forms, strengths and arranged pack sizes,

(ii) pharmacological action,

(iii) recommended dosages,

(iv) contra-indications, interactions and adverse effects,

(v) therapeutic claims,

(vi) position in therapy,

(vii) how the pharmaceutical compares with previously listed pharmaceuticals with respect to the following: efficacy, toxicity and side effects, general equivalence, whether the pharmaceutical is considered a breakthrough, convenience and shelf-life.

(viii) Complementary pharmaceuticals, medical devices, products or things.

Although lengthy, the above list does not represent an exhaustive specification of the dimensions of interest. Temin (1980)[3] identified the following items, in addition to any evaluation of the severity and likelihood of adverse reactions, as relevant considerations when comparing pharmaceuticals:[4]

(i) the actual effectiveness of a drug,

(ii) the method of administration (which can affect the time taken for a drug to work),

(iii) dosage,

(iv) general speed of action, and

(v) rapidity of doses.

Assessing drugs over the correct dimensions is important when modelling the choices made with regard to which treatment option is best for a particular illness. The considerations

---

[2] Pharmaceutical Management Agency Limited. (1993) *Operating Policies and Procedures of PHARMAC.* Wellington, Pharmac. p 16

[3] Temin, P. (1980) *Taking your Medicine: Drug Regulation in the United States.* Cambridge, MA, Harvard University Press. 274p.

[4] Temin, P. (1980) pp.9-10.

outlined here give a picture of the costliness and difficulty of comparing even two drugs. Necessity demands that when evaluating several treatment options comparisons must occur on fewer criteria than those given above.

The essential characteristic and purpose of a drug is to act as a healing agent; it will either cure an ailment or alleviate the symptoms associated with it.[5] The model used to approximate drug choice must take into account that, for any particular patient, no drug is completely predictable in its outcome. Uncertainty exists both in possible drug interactions and in the individual specific side effects a drug causes. Drug interactions are not considered in isolation as they represent a highly complex area of study. Rather drug interactions are modelled as a contributing factor in the distribution of individual specific side effects.

For a drug to be profitable it must obtain a positive market share. As patients typically choose only one of the many drugs available to treat an illness the variation in their choices must occur as a result of differences between patients and/or the information they receive. Such a difference can be incorporated into a model in several ways:

(i) Individual assessments of the merits of drug effectiveness and risk may be allowed to vary.

(ii) The relative importance patients place on consumption and health may vary.

(iii) The effectiveness or side effect of a particular drug may differ for each individual along a pre-defined distribution.

The consumer framework defined here attempts to model how patients approach the inherent risk in taking pharmaceuticals. The choice of the third approach as the method used hinges on its incorporation of the greatest degree of variability in drug risk. Assessments of the relative merits of health and consumption are assumed constant between individuals while quasi-linear utility removes variance in the trade-off between income and consumption.

It is reasonable to assume that any drug will at best promote a full recovery. The quality measure for consumer j for drug i is given the symbol φ_{ij}. Quality may vary between negative infinity (representing death) and, at most, one (signifying a full recovery). Quality is denoted as the difference between two distinct factors; the overall efficacy of a drug (λ) and the side effect

[5] Preventative treatments are ignored since they represent a massive complication to the general framework used here.

(ε) that an individual faces. The overall effectiveness of a particular drug is fixed for all individuals which allows for the adoption of a standard quantity measure (q) for each drug.[6] The quantity of treatment varies between zero, where no treatment occurs, and one, representing a full course of treatment. Full treatment may or may not be sufficient to allow for either a complete cure or suppression of an illness.[7]

The individual specific side effect[8] is of great importance in the choices made by individuals. The choice of the distribution these individual specific side effects are drawn from was based on the concerns that the distribution must promote reasonable assumptions about side effects and that the distribution must not cause excessive problems in evaluation.

These factors suggested that the side effect of a drug on a population be modelled using an exponential distribution. The exponential distribution (with parameter η) is always positive and its probability density function decreases quickly as the severity of side effects increase. The choice of an exponential distribution suggests that side effects are always adverse and generally small, although the possibility exists for significant side effects to occur in small numbers of individuals. The side effect of a drug on an individual is drawn from this distribution and, once drawn, remains fixed for all time.

The lognormal distribution, which also has a strictly positive domain, was not selected because of the difficulty faced when evaluating expected utility. The exponential distribution caused far fewer problems in evaluation which weighed in final considerations over the type of distribution to use.

A normal distribution would unrealistically have assumed that a large adverse side effect was as likely as a large positive one. It is conceivable that an individual may have a strong enough allergy to, say, penicillin for it to be potentially fatal. There is however no realistic parallel when addressing positive side effects. Although small positive side effects no doubt

---

[6] This quantity varies between drugs and may imply that the dose for full treatment may be an important area in which drugs differ.

[7] For serious illnesses that are as yet incurable it is unrealistic to allow a cure to exist at any price yet some form of treatment is still available.

[8] Which, in addition to efficacy, determines quality.

occur it is difficult enough in practice for a doctor to determine exactly the effect a drug has on a targeted illness, let alone on an unrelated one. Restricting side effects to be of an adverse nature only does not appear to be an unjustifiable assumption. Symmetric distributions were therefore not considered for the distribution of side effects. The uniform distribution would have made the model far simpler than the exponential distribution. The uniform distribution would also have assumed that instant death was as likely as a full recovery from an illness. Under this distribution a realistic model of the pharmaceutical market would be impossible to develop.

The probability and cumulative density functions below display the general shape of the distribution of drug quality. Displayed are the probability and cumulative density functions for the values $\lambda = 1$ and $\eta = 0.75$. The relationship $\varphi = \lambda - \varepsilon$ was substituted into the probability density function for side effects ($f_\varepsilon(\varepsilon) = \eta e^{-\eta\varepsilon}$) to obtain the algebraic form of each of these functions.

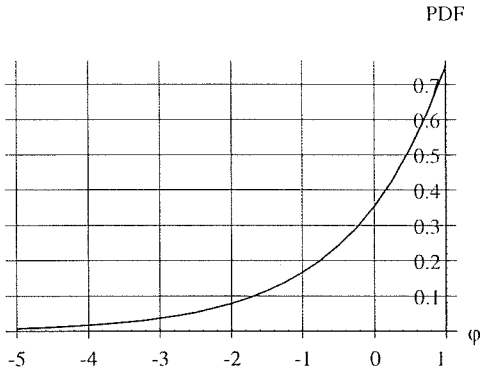


Figure 2.1: Probability density function ($f_\varphi(\varphi) = \eta e^{-\eta(\lambda-\varphi)}$)

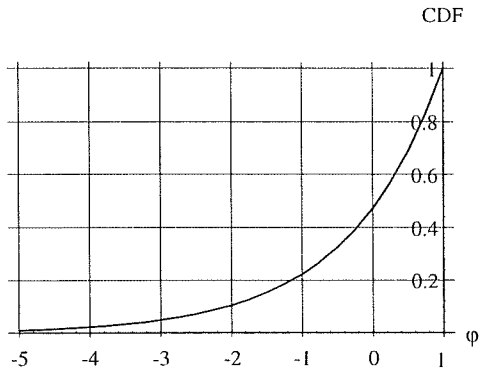


Figure 2.2: Cumulative density function ($F_\varphi(\varphi) = e^{-\eta(\lambda-\varphi)}$)

II. THE DOCTOR-PATIENT RELATIONSHIP

Two major relationships affect drug choice: the connection between doctors and the government, and that shared by doctors and their patients. A transaction cost analysis of the relationship between doctors and the government assesses that the government will choose not to monitor the actions of any particular doctor closely. The government restricts itself to defining a framework within which doctors and their patients decide the form and specifics of treatment. This framework includes rules on the conduct of doctors, the fee doctors receive from the government, and the rights doctors have with respect to prescribing treatments.

The principal-agent model predicts the relationship between doctors and patients badly since for the purpose of incentive compatibility such models predict a positive correlation between the improvement in patient health and payment. In New Zealand doctors receive a flat fee per consultation rather than an outcome-based scheme, rendering the predictions of the standard principal-agent model irrelevant. A possible reason for this lies in the private information patients have about their own health status. Since doctors cannot costlessly verify this status[9] patients can easily under report the effectiveness of treatment in order to avoid paying a greater sum.

Temin (1980)[10] presents a model in which he predicts that three distinct modes of behaviour exist in the relationship between doctors and their patients. Temin's argument appeals to techniques used in different academic disciplines to predict the behaviour of each party. The first of the behavioural patterns addressed is rationality.

Economics as a discipline suggests that decisions attempt to satisfy set goals with some form of optimisation typically involved. Physicians make decisions according to self interest with utility functions that may incorporate an incentive to give quality health advice.[11] Under strict rationality of this type doctors typically also satisfy any conditions imposed upon them by medical associations (codes of conduct) and the government (legal duties).

---

[9] Partly because of the subjective nature of health status.

[10] Temin, P. (1980) pp. 12-17, 163-192.

[11] Be it through an altruistic motive or the benefit accruing to a good reputation.

Temin argues that rational behaviour is most likely to occur where a patient's health is ikely to remain moderately stable over time and where individuals tend to value their autonomy. Time is an important consideration here because there is little incentive for an individual to esearch an illness that is likely to change before treatment is possible.

The second mode of operation was that of customary or traditional behaviour where today's actions are primarily a reflection of actions taken in the past. Sociology and management are both stated to be users of this form of patterned behaviour. Temin presented the organisational theory of the firm as an example of customary behaviour. Here an organisation chooses to behave according to pre-specified rules of thumb so long as results fall within an acceptable range. Once observations no longer lie in the acceptable range the firm searches for a new set of rules. Temin postulated that this form of behaviour characterises those with little autonomy when they face slowly changing conditions.

Command behaviour was said to occur where every party defers to the next level of a pre-determined hierarchy. This system forces compliance and requires a direct threat from doctor to patient to enforce orders. Temin does not justify this assumption or state how or why higher levels of a hierarchy are able to make superior decisions to lower ones.

Temin postulated that individual doctors and patients select one of these modes of behaviour according to the level of change they observe. Demarcation between these types of behaviour is ill defined and the concepts used leave questions unanswered. Traditional behaviour makes sense, but only if there is very little payoff for anyone to find and use information themselves. This is not the case where health changes only slightly over time. Traditional behaviour fares badly with the increasingly quick pace of change within pharmaceuticals because it suggests that doctors are unlikely to use new treatments. Blockbuster drugs appear not to abide by the pattern of behaviour a traditional model denotes. These drugs represent a large improvement on current treatment options and tend to be accepted quickly by the medical fraternity. Prozac represents an example of such a blockbuster. Doctors were initially prevented from prescribing Prozac without a specialist's recommendation but desired the

ability to do so.[12] If doctors acted according to traditional behaviour Prozac, being new, would not have been accepted by doctors let alone fought for.

Command behaviour requires very strong enforcement not seen in reality. While quackery is likely to bring the wrath of a medical association down on a doctor it appears unlikely that an association could successfully coerce doctors into set prescribing practices or prescriptions in everyday matters.

It is valuable to consider the approaches of other disciplines when dealing with the relationship between doctors and their patients. Unfortunately, because these disciplines do not give a better approximation to real life than economics, it seems unwise to continue with them. Rationality has the advantage that, if applied correctly to a problem, it allows ignorance to exist as a rational response. Command behaviour is likely to face problems in the detection of those attempting to discover the quality of drugs while under traditional behaviour it is questionable whether any learning will ever occur.

III. SEARCH METHOD

Economic literature has focused on three different types of search method being the fixed sample, sequential and variable sample search methods. Under a fixed sample search strategy an agent can collect only one sample of data, the size of which is determined by the agent. Under a sequential search strategy the agent can collect multiple samples of data but each of these samples can encompass only one observation. Finally, under a variable sample size strategy the agent can collect multiple samples of data, the size of which are determined by the agent.

Since both the fixed sample and sequential search strategies are simply special cases of the variable sample size strategy (VSS) it is expected that where this strategy is available it will be used by agents. Harrison and Morgan (1990)[13] analysed the three options above and found that agents use a VSS strategy in preference to either fixed or sequential search strategies.

---

[12] *The Press*, 12 August 1996

[13] Harrison, G.W. and Morgan, P. (1990) Search intensity in experiments. *The Economic Journal* 100(401):478-486.

The availability of an unrestricted VSS scheme in the case of pharmaceuticals is questionable. In order to use either the fixed sample strategy or an unrestricted VSS strategy it must be possible for patients to test multiple pharmaceuticals simultaneously. Interactions between drugs are complex and so it is unlikely that doctors will be able to consistently ascertain the effects of individual drugs when patients simultaneously test multiple drugs. This difficulty is incorporated by restricting strategies so that only unit sample sizes are permitted. This removes the fixed sample search from consideration and restricts the VSS to a simple sequential search strategy. The sequential search strategy is thus adopted as the method of search here.

If, as is normally the case, doctors have superior information about the quality of drugs then they will naturally take the primary role in prescribing. The doctor has a set estimation of drug quality and will ask the patient about the specific side effects they observe from tested drugs.[14] Doctors rank relevant drugs according to their own estimation of drug quality in order to maximise their estimation of expected utility for the patient. This estimation attempts to proxy the trade off a doctor makes between the cost and likely effect of a drug when deciding on treatment recommendations. Information can be passed to patients by outlining available treatment options and making recommendations.

Once the doctor prescribes a particular drug the consumer can take a small test dose. This sample is infinitesimal in size and serves only to inform the patient of the specific quality of that particular drug. Patients decide whether to continue on their current choice of treatment or return to the doctor (at a cost) in order to request a different drug.

[14] This estimation is a function of the information doctors receive from their own experiences, as well as from the drug companies, patients, Pharmac and health lobby groups.

IV. DRUG CHOICE GIVEN ESTIMATES OF DRUG QUALITY

Utility is assumed to be a function of affordable goods. Illness is assumed to restrict the ability of a patient to earn. The basic utility function used here is found below by substituting an appropriate budget constraint into the utility function.[15]

$$\begin{aligned} U_{ij} &= y_{ij} \\ p_i q_{ij} + y_{ij} &= m - L(1 - \varphi_{ij}\sqrt{q_{ij}}) - k, \\ U_{ij} &= m - p_i q_{ij} - L(1 - \varphi_{ij}\sqrt{q_{ij}}) - k. \end{aligned}$$

Here φ_{ij} and q_{ij} are the quality and quantity of drug i selected by patient j, and y_{ij} is her consumption of all other goods given a selection of drug i. The price of a full course of treatment above appears as p_i, while m is the income of a patient. L is the potential loss in income from illness, and k the cost of searching. This search cost covers any charges borne by the patient other than the direct cost of purchasing a filled prescription. The search cost includes the cost of a doctor's appointment, any travel costs associated with treatment, the opportunity cost of the time taken for the appointment, the filling of any prescriptions, and the opportunity cost of the time to test the drug.

The quasi-linear representation for utility found above ignores income effects except where treatment is particularly costly. In reality, income effects are likely to be of most importance in the case where treatment is expensive. A quasi-linear utility function will still capture income effects when they are likely to be significant.

The practicalities of this project required numerical approximations to some evaluations.[16] These approximations did not converge where treatment levels varied between zero and one. This resulted in the necessary concession of restricting the choice of an individual to either zero or full treatment. In favour of allowing only a simple binary choice as opposed to the full range [0,1] is the reluctance of doctors to prescribe partial treatments. Patients must pay for

---

[15] This utility function here may be misleading given that quantity is later restricted to the values 0 and 1. The equation shown here is still the desired form and the restriction of quantity to the values of 0 and 1 is itself a result of the form used here.

[16] The problem occurred when trying to numerically integrate to find the consumer surplus in the marketplace.

pharmaceuticals before the commencement of treatment so consumption up to the purchased level will take place whenever quality is positive.

Drug treatment is no longer continuous but instead is a series of discrete jumps. The number and frequency of jumps depends on the form of the prescription regarding repeats and dosage. The restriction of quantity to the binary choice {0, 1} may be reduced to assumptions that full treatment is purchased in one transaction and that pharmaceuticals cannot be sold to third parties. Displayed below are the utilities of both no and full treatment along with the decision rule patients will use to choose whether or not to accept treatment.[17]

$$U_{ij}\Big|_{q_{ij}=1} = m - p_i - L(1-\varphi_{ij}) - k.$$

$$U_{ij}\Big|_{q_{ij}=0} = m - L - k.$$

$$q_{ij} = \begin{cases} 0 & \text{if } \varphi_{ij} \le \frac{p_i}{L} \\ 1 & \text{if } \varphi_{ij} > \frac{p_i}{L} \end{cases}.$$

From this expression we can derive the expected utility of drug i for consumers for whom φ_{ij} is unknown. The largest of these expected utilities (which are conditional on expectations of λ and η) will be selected as the first drug for testing. The patient chooses the best available drug given the information they either receive or research themselves. The patient, committed to the choice of a particular drug, proceeds to take an infinitesimal test sample. The test sample reveals the true value of φ_{ij} to the patient who then chooses whether to continue with this treatment, try a different drug, or simply live with their illness.[18]

Drug qualities are assumed to be uncorrelated across individuals so that a bad quality observation for one drug gives no indication of the quality of any other drug.[19] The only time a consumer will choose to give up searching (other than to return to a drug already tested) is when all drugs representing an increase in expected utility[20] have been tried and rejected. If a drug makes it to the market it is reasonable to assume that its expected utility for all patients is superior to that of selecting to take no treatment.

---

[17] See Appendix 2.1.

[18] Given the information the doctor provides regarding the expected drug distributions. Patients need not know the drug distributions, rather they need know only the observed qualities of tested drugs.

[19] Generics, which are a general exception to this statement are covered in Chapter 8.

[20] That is, drugs with $EU > m - L$.

If a patient is unhappy with the level of quality observed in their current choice of drug they have the option of returning to their doctor. A patient knows the qualities of the current and any past discarded drugs so a decision of whether to continue searching will be based on the best available alternative. Further search will occur only if the expected utility from searching exceeds the utility of their next best option. The expected utilities for both searching and accepting a previously rejected drug are shown below:

$$E\left[U_j\Big|_{search}\right] = \max_{i \in T \setminus R}\left\{E\left[U(\tilde{\varphi}_{ij})\right]\right\} \qquad E\left[U_j\Big|_{no\ search}\right] = \max_{i \in R}\left\{U(\varphi_{ij})\right\}$$

where T is the set of all relevant pharmaceuticals and R is the set of all rejected pharmaceuticals

V. EXPECTED UTILITY

Before continuing further it is worthwhile to examine the general shape of the expected utility function. Appendix 2.1 derives the following expression for expected utility:

$$EU_i(p_i, p_j, \lambda_i^e, \eta_i^e) = (m - L - k) + L(\lambda_i^e - \tfrac{1}{\eta_i^e}) + \tfrac{L}{\eta_i^e} F_i^e(\tfrac{p_i}{L}) - p_i$$

The graphs below show changes in expected utility as the price charged for treatment increases as well as where effectiveness (λ) and the compactness (η) of the outcome distribution are varied.

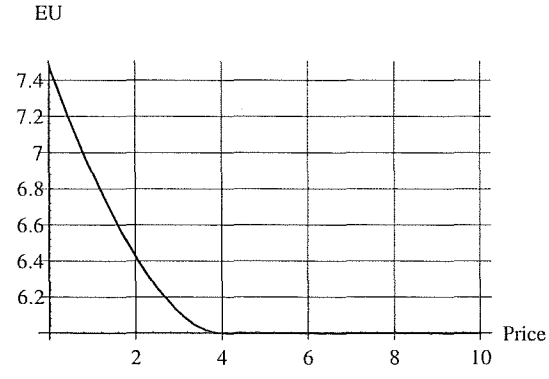


Figure 2.3: Expected utility: λ=1, η=1, m=10, L=4

Increasing price also increases the level of quality required to make consumption worthwhile and decreases utility where treatment occurs. These effects combine to produce an expected utility function that decreases in price.[21]

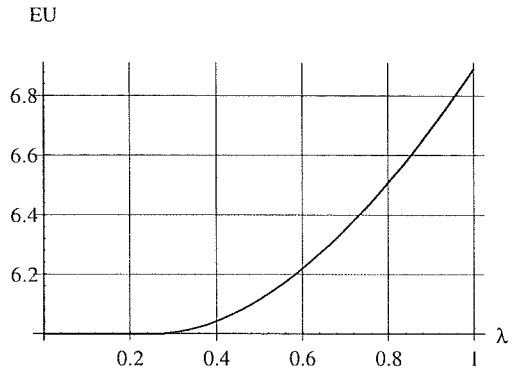


Figure 2.4: Expected utility: p=1, η=1, m=10, L=4

The more effective the drug is generally the better the results for a patient will be. The value of the drug to a patient increases as does the likelihood of choosing to take the drug. These effects correctly suggest that expected utility will increase in efficacy.

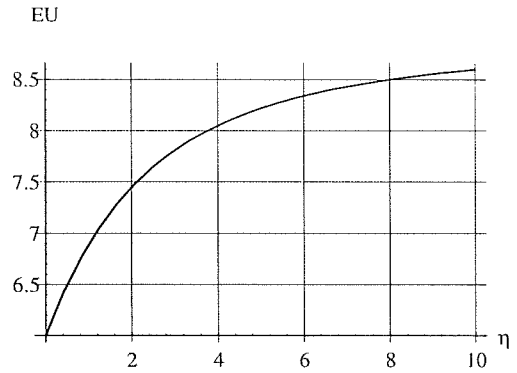


Figure 2.5:Expected utility: p=1, λ=1, m=10, L=4

The expected value of the exponential side effect distribution $f_\varepsilon(\varepsilon)=\eta e^{-\eta\varepsilon}$ is $1/\eta$ while the variance of the side effect is $1/\eta^2$. The quality distribution then has a mean quality of $\lambda-1/\eta$ and variance $1/\eta^2$. A higher value of eta then corresponds to a higher average quality for drugs and a smaller variance in outcomes which promotes greater utility. Alternatively, the proportion of patients facing a negative drug quality is $e^{-\eta\lambda}$ so that the higher is η, the lower is the chance that the patient faces a low drug quality.

---

[21] Consumption occurs if $\varphi > \%$. If $p > \lambda L$ then $\varphi \le \lambda < \%$ and no consumption occurs. Where $p > \lambda L$ no treatment is ever selected and expected utility is $m - L = 6$.

VI. INTERTEMPORAL ASSUMPTIONS

The aim of the patient model derived in this chapter is the creation of drug quantity functions dependent only on the following: the price of all relevant pharmaceuticals, the quality characteristics of these pharmaceuticals and the estimation of doctors regarding these quality characteristics.

Where quantity is observed to change over time it is desirable that this change is a direct result of changes in the above variables rather than any functional dependence of quantity on time. To derive such quantity functions further restrictions must be made affecting both the distribution of patients and the information patients hold at the beginning of each period.

(1) Period length

Choosing an appropriate period length is essential in correctly identifying the proportion of users of each drug. The following information is necessary when attempting to find the proportion of patients using each drug in the very short term:

(a) How many people have just found out they have an illness for the first time? These people have no personal history regarding the quality of drugs used to treat this illness. This affects the actions individuals are likely to undertake in future periods since they may still be searching rather than taking treatment.

(b) How many people are testing the quality of drug i?

(c) How many people already know the quality of drug i?

(d) How many patients are suffering this illness for the first time? If a consumer is suffering a reoccurrence of a previous illness they generally know which treatment is optimal and a successful treatment is repeated. Exceptions to this rule can occur where their doctor's estimation of drug quality has changed or new products have emerged.

These considerations overcomplicate the analysis of the model. The above concerns are averted by examining only the final treatment choices so that intermediate actions taken by consumers are ignored.

(2) Removing intertemporal effects in the quality distribution

A further assumption is required to stabilise the distribution of outcomes. Both the duration and chance of reoccurrence of an illness must be independent of the individual specific quality of any drug. Suppose that this were not the case and that a large portion of those who suffered negative side effects in the previous period would suffer a relapse. In the next period there are two types of patients; those who manifest a new illness and those who have suffered a relapse. Those suffering a new illness come from a distribution as defined earlier while those suffering a relapse tend to lie in the tail of the distribution of quality. There is an overall bias towards large negative side effects and the exponential distribution of quality is invalid when used as the distribution of patients. Imposing independence of duration and quality alleviates this potential problem.

(3) Removing intertemporal effects in patient choice

Two further assumptions are necessary in order to make certain that patients faced with the same drugs, prices and information will make the same decisions. The major effect of these assumptions is to restrict the information patients can transfer intertemporally. If patients in one period have superior information to patients in another period (other than improvements in the knowledge of doctors) it is possible that their choices may differ. One of the aims of the model developed here is time-independence of choices which will be violated if intertemporal transfers of patient specific knowledge are permitted. The assumptions required to avoid such transfers are: that illnesses last only one period, that patients of different types fall ill with equal probability, and that a fixed number of patients fall ill randomly within an infinite population.

The first of these assumptions restricts the most obvious of information transfers. If patients are ill for multiple periods then they will carry pertinent information for several periods. The second assumption implies that those who are ill are distributed according to an exponential distribution. This assumption forces the side effect distribution of patients to equal the distribution of side effects for the population at large.

The second method by which information may be transferred is where a patient suffers a relapse. Where a fixed sample of patients are drawn from an infinite population the chance of any particular individual being selected is zero, as is the chance of any individual suffering a

relapse. Where illness does not reoccur it is possible to address each period in a one-off fashion with no prior knowledge except that which doctors hold. This result is necessary due to the effect of knowledge transferred by patients from one period to another where two or more treatment options exist and where the patient faces at least two high individual qualities.

Suppose that between two periods the estimates a doctor has over drug characteristics change. Suppose further that in the first period a particular patient may have tested drug A first and selected it on the basis of expected utility without testing drug B. In the second period the same consumer, without prior knowledge and with the doctor's new estimation of drug quality would choose to test drug B first and, perceiving a high quality, would accept this drug for the purposes of treatment. If, in this second period, the patient had known the quality of drug A she may have chosen to use it in preference to drug B. The prior knowledge of the patient is significant to her decision, suggesting that the proportion of patients using a particular drug is dependant on the number and types of patients suffering a reoccurrence of illness. The infinite population assumption prevents this complication to the model by forcing the chance of reoccurrence to zero.

VII. THE PROPORTION OF PATIENTS USING A PARTICULAR DRUG

One of the advantages of using a binary choice in treatment is that it removes the necessity of separate indices for both quantity and the proportion of patients using a drug. The expression below is only an outline of the share of patients using each drug.[22] Note that because some patients will choose to use none of the available drugs the market share of a drug does not accurately reflect the proportion of patients using that drug.

The proportion of patients using drug 1 (where drug 1 is superior in expected utility) consists of two groups within a duopoly: those who sample only drug 1 and find it of sufficient quality to continue without testing drug 2, and those who sample both drugs and find drug 1 to be superior to both drug 2 and taking no drugs.

---

[22] For a formal derivation of these terms see Appendix 2.3.

Below are the aggregate quantities of each drug and the proportion of patients who choose to take no treatment:[23]

$$Pr(D_1) = Pr(U_1 > EU_2 - k) + Pr(U_1 > U_2,\ \varphi_1 > \tfrac{p_1}{L})(1 - Pr(U_1 > EU_2 - k))$$

$$\text{and } Pr(D_2) = Pr(U_2 > U_1,\ \varphi_2 > \tfrac{p_2}{L})(1 - Pr(U_1 > EU_2 - k))$$

$$Pr(ND) = Pr(\varphi_1 \le \tfrac{p_1}{L}) Pr(\varphi_2 \le \tfrac{p_2}{L})$$

Only two drugs are typically considered because of the algebraic complexity in evaluating integrals contained in these expressions. An alternative expression for the likelihood of a consumer using any particular drug appears below:

$$Pr(D_1) = (1 - F_1(\varphi_1^*)) + \int_{\frac{p_1}{L}}^{\varphi_1^*} f_1(\varphi_1) F_2(\varphi_1 - \tfrac{(p_1 - p_2)}{L}) d\varphi_1$$

$$Pr(D_2) = F_1(\varphi_1^*) - \int_{\frac{p_1}{L}}^{\varphi_1^*} f_1(\varphi_1) F_2(\varphi_1 - \tfrac{(p_1 - p_2)}{L}) d\varphi_1 - F_1(\tfrac{p_1}{L}) F_2(\tfrac{p_2}{L})$$

$$Pr(ND) = F_1(\tfrac{p_1}{L}) F_2(\tfrac{p_2}{L})$$

where drug 1 is superior on the basis of expected utility and

$F_i(\bullet)$ is the CDF of the quality of drug *i*,

$f_i(\bullet)$ is the PDF of the quality of drug *i*, and

φ_1^* is the minimum test value of φ_1 for which drug 1 is selected without further testing.[24]

---

[23] These proportions are derived in Appendix 3.1.

[24] A more complete definition is given in Appendix 3.1. Note that this is the normal case only - for the case where expectations are highly unrealistic see the appendix.

CHAPTER 3

PRODUCER CHOICE

I. THE CHOICE OF MODEL CHARACTERISTICS

The assumption that drug companies are rational profit maximising entities reveals very little about their choices and activities. In order to predict the actions of these firms a more precise determination of their available choices and beliefs is necessary. For a model definition to be complete it must define the strategic items of choice for the producer as well as the beliefs held by producers over their competitor's reactions when making their choices. Discussion on these points will focus around the Cournot and Bertrand models in addition to the issue of whether quality is a strategic variable for pharmaceutical companies.

Before proceeding it is worthwhile to clarify the terminology used when referring to the quality of drugs. If drug A is termed superior then for a consumer uninformed about the individual qualities they face the expected utility of drug A exceeds that of its competitor. If a drug is of a greater overall quality then its outcome distribution first order stochastically dominates that of its competitor.[1] Where concepts other than those outline above are used in the comparison of pharmaceuticals further explanation will be given.

(1) Cournot vs. Bertrand

The Cournot model of duopoly postulates that producers use quantity as a strategic variable with price determined endogenously according to the inverse demand curve. Producers here determine quantity based on an estimation of the other firm's output.

---

1 Drug A first order stochastically dominates drug B if the distributions of the drugs differ and the probability of an individual observing a quality above x is at least as great for drug A than drug B, regardless of the x chosen.

The Bertrand model of duopoly proposes that each producer sets its own price given an estimation of the price of any other firm. The demand curve defines quantity endogenously in the Bertrand Model.

Both the Bertrand and Cournot approaches have merit and will normally result in different predictions even when used in the same context. As an example, in a differentiated product model where demands are linear functions of price a Bertrand model will suggest lower prices than its Cournot equivalent.[2] In a non-differentiated model where marginal costs are constant a pronounced division exists between the models. Here the Cournot model predicts that the price charged will lie below the price either firm would charge if they were the only firm in the market but will still be in excess of marginal costs. The existence of a second firm has made the market more competitive, but not perfectly so. The Bertrand model in this case predicts that price will equal marginal cost and the competitive outcome will occur. The Bertrand model predicts that with two or more firms competitive pricing will occur whereas the Cournot model requires an infinite number of firms for this pricing result.

In the *Economics of Industrial Organisation* Davies and Lyons suggest that the decision between the Cournot and Bertrand models hinges on the type of market and the process by which equilibrium occurs.[3]

> Clearly, it makes a difference whether firms choose prices or quantities. What grounds do we have for choosing between them? First, and perhaps most importantly, there is the question of the type of the market. In some markets (for primary products, stocks and shares) the people who set prices (brokers) are different to the producers. There exists what is essentially an auction market: producers/suppliers release a certain quantity into the market, and then brokers will sell this for the highest price possible (the market clearing price). The Cournot framework would thus seem natural where there are auction markets. While there are auction markets, there are also many industrial markets without 'brokers', where the 'typical' sort of market which concerns industrial economists is not an auction market, but a market with price-setting firms. How can the use of the Cournot framework be justified in markets with price-setting firms?
>
> It is often argued that the choice of Bertrand or Cournot competition rests on the relative flexibility of prices and output. In the Bertrand framework, firms set prices and then produce to order. Thus once set, prices are fixed, while output is perfectly flexible. In the Cournot framework however, once chosen, outputs are fixed, while the price is flexible in the sense

---

[2] Davies, S. and Lyons, B.(1988) *Economics of Industrial Organisation.* Essex, Longman p 133, 135

[3] Davies, S. and Lyons, B.(1988) pp 134-135.

that it clears the market. Thus the choice between the two frameworks rests on the relative flexibility of price and output. This is of course an empirical question, but many would argue that prices are more flexible than quantities (e.g. Hart 1985), and hence the Cournot equilibrium is more appropriate.

An argument of the type given above by Davies and Lyons requires that some uncertainty exists in demand between periods. The concept of "relative flexibility of quantity and price" attempts to ask whether firms set price and then allow quantities to equilibrate the market or alternatively set quantities and leave price to equilibrate the market. The downside of the equilibrium concept in a model encompassing uncertainty is that it complicates the idea of what an equilibrium involves.

An equilibrium in pure strategies within an uncertainty free game requires constant prices and quantities. In an equilibrium where uncertainty exists either prices or quantities will equilibrate the market in the sense that quantity supplied equals market demand at the final price level. Below are demand and supply diagrams for a firm in each case.[4]

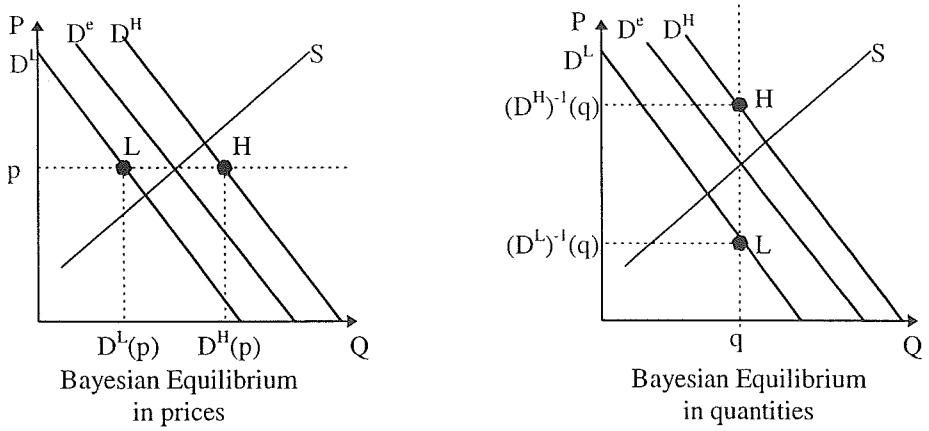


Figure 3.1: Bayesian equilibria in prices and quantities.

Where, in reality, a Bayesian Equilibrium in prices exists a Bertrand model is valid when modelling the market in an uncertainty free framework. Where the Bayesian Equilibrium is in quantity a Cournot model is more appropriate in the simpler setting. The model used does not attempt to take this uncertainty into account because of its inherent difficulty. Under uncertainty it will be very difficult to predict the paths of prices, quantity and knowledge about drugs over time.

---

[4] Where H and L refer to high and low levels of demand, respectively.

In the market for pharmaceuticals, drug companies determine prices after consideration of the regulatory framework they inhabit. Where an obvious regulatory framework exists it will tend to target prices in some fashion. Internationally measures to limit prices fall into several different categories:

(i) measures imposing greater costs on consumers for more expensive drugs (includes proportional cost sharing and reference pricing),

(ii) product by product price controls, or

(iii) indirect controls on price through profit controls (where excess rents are not simply dissipated).

One possible reason price, rather than quantity is targeted is that price is more predictable in the marketplace. Greater variability in quantity infers that a Bayesian Equilibrium in prices occurs and suggests a Bertrand rather than a Cournot model be used.

The market does not appear to fall in the general realm of auction markets because no obvious auctioneer exists. The relative flexibility of prices and output is an interesting comparison and should be considered in a small enough time frame to appreciate full volatility. In order to determine the proportion of patients using each drug it was first necessary to abstract from a sequential search process. This abstraction relied on increasing period lengths in order to remove variation in quantities caused by patients being at intermediate stages in the search process. This variation in quantity suggests the Bertrand model be used.

The final argument for the use of a Bertrand rather than a Cournot model lies in the sequential search framework derived in Chapter 2. It is assumed that patients, when testing drugs, face constant prices for drugs and have the ability to buy any quantity they desire. The search framework introduces small variations in demand that a Bayesian Equilibrium in quantity suggests would render price variable in the short term. Such a Bayesian Equilibrium would violate the assumptions of the search model whereas a Bayesian Equilibrium in prices would not.

(2) Product quality as a strategic variable

The essence of whether or not quality is a strategic variable relies on the process by which new products enter the market. The Researched Medicines Industry Association of New Zealand (RMI) estimates that in a worldwide setting only one compound in 10,000 makes it to the marketplace.[5] The chance of any specific compound proving to be a marketable drug after testing and a lengthy approval process is slim.[6] The likelihood of a drug company being able to significantly increase the quality of a marketable drug appears even more negligible as the process of innovation is neither a predictable nor a deterministic one. The characteristics of quality (λ_i, η_i) for a new chemical entity are assumed to be random while copycat drugs and generics are predictable in terms of the quality of the chemical entity they mimic.

Drug companies appear to have insufficient control over quality for it to act as a strategic variable so when modelling pharmaceutical companies the prices of drugs are the only relevant strategic variables addressed.[7]

II. PRODUCT DIFFERENTIATION

Pharmaceutical companies compete on the basis of price but do so in the knowledge that their drugs differ from those of their competitors. In the literature on product differentiation models fall into two distinct types; the representative consumer and the spatial model. Carlton and Perloff define these types of models in the following way:[8]

---

[5] Researched Medicines Industry Association of New Zealand. (1993) *An agenda for medicines in health: 1994 and beyond.* Wellington, RMIANZ. p 8. The number of drugs required at the trial stage for a single marketable drug will of course be much lower than 10,000. Even so, other than where the make up of drugs is fine-tuned, quality is assumed to be random.

[6] Although small changes to the makeup of an established drug may improve its quality. An example of such a change is in Amoxycillin with Potassium Clavulanate which has a better side effect profile than the original chemical entity of Amoxycillin.

[7] There is also potential for advertising to act as a variable here since this may affect the estimation of doctors over the quality and applicability of alternative treatments. Under the search model of Chapter 2 advertising was to be a strategic variable but after necessary modification of the model this will no longer be possible. The rationale for the modification of the model will be explained later in this and following chapters.

[8] Carlton, D. and Perloff, J. (1994) *Modern Industrial Organisation.* 2nd edition, Harper Collins. p 282.

> [In the] representative consumer model, all firms compete equally for all consumers who typically buy from each firm. This model might be used to study the restaurant market, in which firms produce differentiated products (such as different ethnic cuisines), but all compete for the same customers.
>
> In the other, the *spatial* or *location* model, each consumer prefers products that have certain characteristics or are sold by firms located near them and is willing to pay a premium for these preferred products. Moreover, the consumer may not care greatly about the price of some other goods in the market. For example, a consumer whose favorite cereal is Kellogg's corn flakes is more sensitive to the relative price of Post's corn flakes that to the relative price of Nabisco's sugar-coated shredded wheat. The other brand of corn flakes is a much better substitute than other types of cereal.

The pharmaceutical model used here falls into the location class of model. Location consists of the particular position each patient occupies in the quality distribution of each drug. Different locations allow two patients to attain different utilities from the same drug, introducing variation into decision making. In addition, patients use only one drug and not a portfolio of drugs having the same pharmaceutical effect, as would be predicted under a representative model. Finally the point made above with respect to consumers relative indifference over the price of some commodities in the market holds. If a drug has a negative quality measure for a patient then the actual price charged is irrelevant since that consumer will never select it in preference to using no drugs at all where the consumer price is positive.

Before addressing the problem of product differentiation in the pharmaceutical market it is worthwhile to first examine the Bertrand model without such differentiation. This exercise seeks to highlight the standard results of product differentiation. Section 1 addresses the case of non-differentiated models while 2 deals with the standard results of the heterogeneous model. The sections beyond those concerning product differentiation seek to address the specific case of the pharmaceutical market. Neither of the earlier sections completely covers the sequential search model as both assume that consumers know their utility given consumption of different goods. When patients make a final decision on treatment the costly nature of information may dictate that some drug qualities might not be known.

(1) General results of a Bertrand model with homogeneous products

Before looking at the behaviour a differentiated Bertrand model predicts for an actual market it is worthwhile to first focus on a homogeneous product case. Future arguments will rely on reasoning close to that given in this section.

The classical Bertrand model focuses on the pricing decisions of a duopoly where both firms face constant returns to scale and have the same marginal cost (c). Each firm may manipulate only the price of its own good, which it sets equal to marginal cost in equilibrium. Where both firms charge at marginal cost the unique Nash equilibrium of the Bertrand game occurs.

In order to prove the above statement two propositions must be established; firstly that "the strategies above promote a Nash equilibrium", and secondly that "there can be no other Nash equilibrium in the game". The latter of these propositions is assessed first. Suppose an equilibrium exists with each firm charging a different price so that the low price firm prices above c and gains the entire market. The firm with the higher price has an incentive to match the lower price and receive half the market. The lower priced firm has an incentive to increase its price to just below the higher price. Any equilibrium with market price above c must therefore involve both firms charging the same price or else at least one firm will have an incentive to change the price it charges.

Any point where the common price is above c will be prone to undercutting as both firms have an incentive to decrease their price. There can therefore be no equilibrium with price above c. No equilibrium with price below c can exist since the low price firm has an incentive to increase price to at least c. The latter proposition is therefore true.

The point at which both firms charge marginal cost is a Nash equilibrium since neither firm has an incentive to change their price. A price decrease will not occur as this would result in a loss as opposed to zero profits. A price increase would not affect profits as when $p = c$ profits are zero, the same profit obtained if a firm increased its price above marginal cost and faced zero consumption.

(2) General results of a Bertrand model with heterogeneous products

Product differentiation in a location model is dependant not only on the actual differences between commodities but often purely on perceived differences. The best known example of this is the difference between Coca-Cola and Pepsi. Before blind trials many people state a preference between Coke and Pepsi but relatively few can identify the brands by taste.[9] The distinction between actual and perceived differences is especially important in a search theory framework.

The most famous of all location models is Hotelling's 1929 model[10] where sunbathers occupy a beach served by two ice cream sellers. These vendors compete for their custom on the basis of price and proximity. The model distributes consumers uniformly along a line segment and queries where firms will choose to locate themselves and how they will choose to price. If firms set a constant price then each firm, knowing the location of the other, will seek a new location just on the larger side of the continuum from its opposition. The resulting equilibrium will see both firms locate arbitrarily close to the centre of the beach.

If firms are unable to move then the standard Bertrand result no longer holds. Here two firms are no longer sufficient to guarantee a perfectly competitive equilibrium. Take one firm and hold its competitor's price constant at marginal cost. The other firm prices knowing that even if it charges above marginal cost it will retain some of the customers located closer to it than to its competitor. The outcome where both firms charge marginal cost will not be an equilibrium as some profits (achieved where price is above marginal cost) will be preferable to none.

The equilibrium where firms have pre-defined positions sees the firm closest to the largest number of consumers charging a higher price. This is analogous to a firm producing a higher quality good being able to charge above its competitor in equilibrium. There is therefore a premium attached to the good with the superior location.

---

[9] Carlton, D. and Perloff, J. (1994) p 283.

[10] Hotelling, H. (1929) Stability in competition. *Economic Journal*:41-57.

A non-existence problem arises where both firms can freely choose both price and location. Without modification the simple Hotelling model yields no further results. Since the quality characteristics of a drug are constant and invariant over time this particular version of the non-existence problem will not arise in the pharmaceutical model examined here.

III. EXPECTED UTILITY

The expected utility of a drug is vital because of the sequential search method employed by patients in finding the correct course of treatment. The drug with the superior expected utility has a natural advantage as patients test this drug before deciding whether to test the other drug available. Suppose that drug 1 is the superior drug in an industry. Where drug 1 achieves utility above that of the expected utility of drug 2 treatment occurs without further testing. Of those testing drug 2 not all will select to use it, the others finding that drug 1 and/or no drugs at all represent a better treatment option. The net result will be that drug 2 has a much lower consumption than drug 1 even if the expected utilities are quite close. Figure 3.2 attempts to illustrate the increased market share of a superior good (labelled as drug 1).

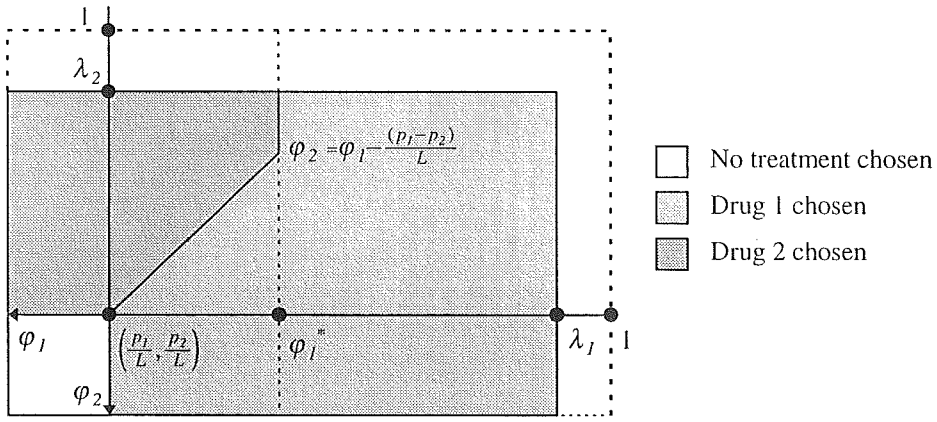


Figure 3.2: Treatment choice.

Notice that the line representing marginal consumers (labelled as $\varphi_2 = \varphi_1 - \frac{(p_1 - p_2)}{L}$) extends only to φ_1^*. If patients knew the quality of both drugs there will be some who would choose to use drug 2 who would not test drug 2 under a sequential search framework. The dark shaded area in Figure 3.3 below represents these consumers.

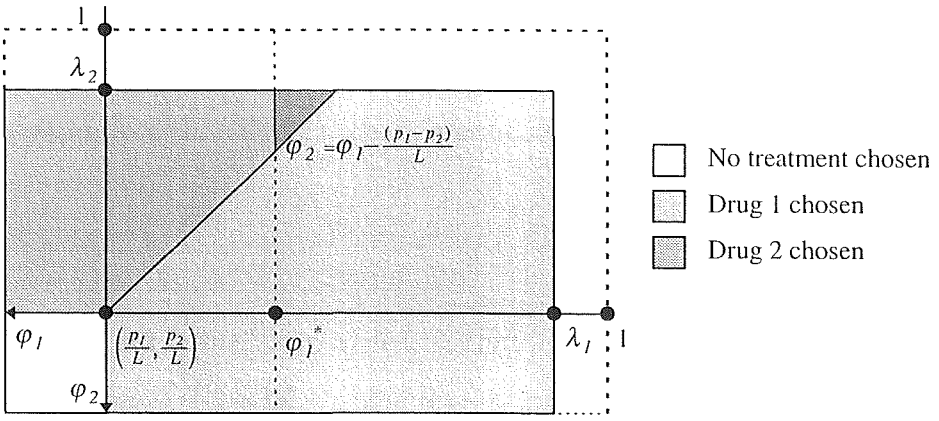


Figure 3.3: Gains accruing to the drug with superior expected utility.

The dark shaded area is a transfer of patients from drug 2 to drug 1, and is due to the superior search position of drug 1. These patients give an additional payoff to being the superior drug.

By way of an example: Suppose both drug 1 and drug 2 have λ_i=1 and η_i=1 with p_1=1 and p_2=1.01, and that patients know this. The expected utility of drug 1 is 6.2466 and the expected utility of drug 2 is 6.2411. The \$0.01 difference in price translates to 19% more patients choosing drug 1 than drug 2 ($Pr(D_1) = 0.4940$, $Pr(D_2) = 0.3037$). Where the characteristics of drugs are similar, we can expect considerable competition between drugs in order to achieve the highest expected utility level.

IV. THE COMPOSITION OF A REACTION CURVE

The model used here is that of a duopoly where each firm faces a constant marginal cost of production c_i. Having only two firms is essentially a simplifying assumption that aids in a clear exposition of the definition of the reaction curves and the properties any resulting equilibrium will have.

(1) The reaction curve of a superior drug

Suppose that the price of a drug is such that it has a higher expected utility than its alternative. It is free to price at any level so long as it is indeed superior at the price chosen. Suppose also that the price of the other drug increased. Now the superior drug, being a substitute

for the inferior, experiences an increase in demand which it accommodates by increasing the price it charges slightly. The reaction curve of a drug over the range of prices where it is optimal to act as a superior drug should therefore be upward sloping.

(2) The reaction curve of an inferior drug

Suppose that a drug has a lower expected utility than its alternative. Patients who use the inferior drug are normally those for whom the superior drug is of poor quality while the inferior drug is of a quality sufficient to prompt treatment. The majority of those using the inferior drug face the decision of whether to use the inferior drug or to take no treatment. The firm producing the inferior drug can take advantage of an effective lack of competition and charge a relatively high price for its wares. Because it faces a much smaller demand the profits made by an inferior firm are likely to be smaller than those made by a superior firm in the same market.

Suppose now that the price of the superior drug increases. The firm producing the inferior drug faces a slightly increased number of patients for whom the superior drug is likely to be worse than taking either the inferior drug or taking no treatment at all. The firm producing the inferior drug is expected to increase its price very slightly to take advantage of this.

(3) The reaction curve of an undercutting drug

For some levels of prices it is unsurprising that a situation akin to the homogenous Bertrand game evolves. Here the most important consideration in maximising profits is to be the superior drug on the basis of expected utility. Accordingly a firm will decide to undercut the expected utility of their competitor by an epsilon in order to obtain the status of superior drug. Note that an equilibrium cannot occur where both firms are seeking to undercut since at least one firm will have an incentive to cut price in order to become the superior drug.

(4) The composite reaction function

In order to combine the three types of status described in Sections 1-3 we must consider the profit function. The correct case for profit maximisation is identified for every value of the competitor's price and the reaction curve for a firm derived. Every firm will have a discontinuity in its profit function at the level where price equalises the drugs' expected utilities. Prices below

that level correspond to where the firm's drug is superior, while for prices above this level the drug has an inferior status. Below is a sample diagram to illustrate this point:

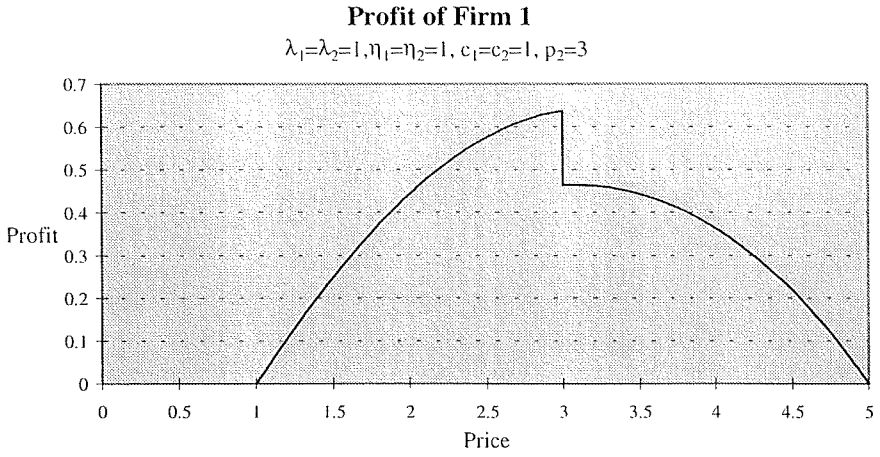


Figure 3.4: Sample profit function.

The general shape of the above diagram corresponds to that of an undercutting firm. Here there is no local maximum where the drug has superior status and the local minimum (where it is inferior on the basis of expected utility) promotes less profit than undercutting. The determination of optimal pricing behaviour is simplified by relying on four generalised cases of the profit function. Figure 3.5 analyses the first two of these cases while Figure 3.6 addresses the latter two.

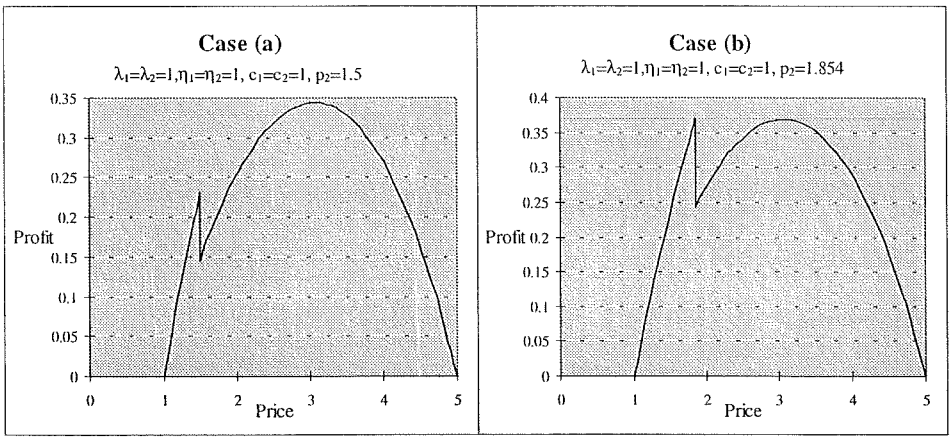


Figure 3.5: Sample profit functions (a) and (b).

For low enough values of the competitor's price the profit function looks case (a). The price charged by the other firm is so low as to prevent undercutting from being a serious option for the firm. The profit maximising point is the local maximum where the price of the drug is above the level that equalises expected utilities. As the price charged by the competing firm

increases the firm becomes less eager to accept inferior status for its product. Case (b) represents the threshold for the competitor's price where the firm is indifferent between undercutting and accepting inferior status.

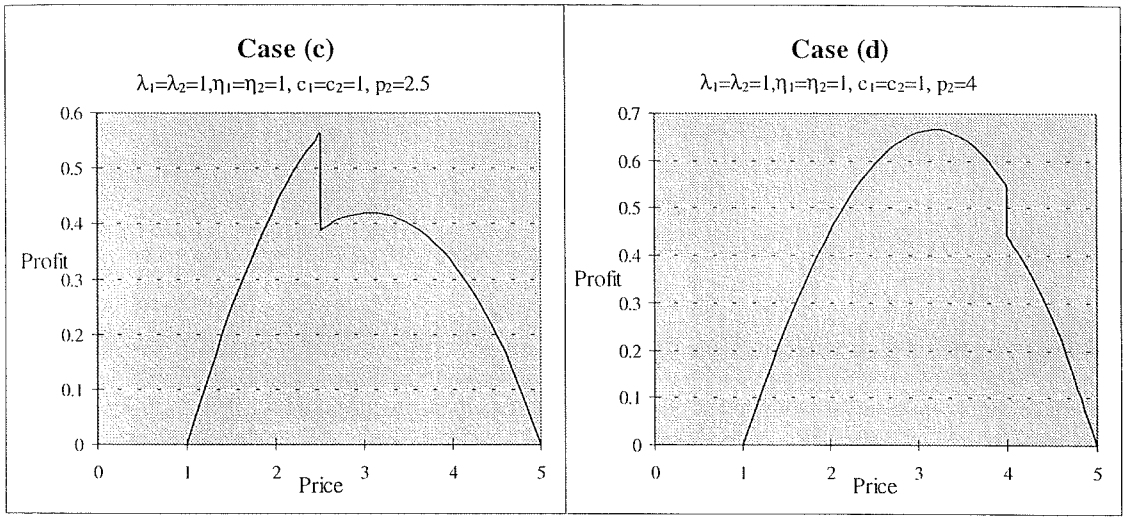


Figure 3.6: Sample profit functions (c) and (d).

Case (c) above represents the range where undercutting the competition's expected utility by an epsilon is a dominant strategy. The local minimum present when accepting inferior status is itself inferior to that achieved when successfully undercutting. The final case addressed is that where it is optimal to price below the level required to achieve superior status on the basis of expected utility. Here a local maximum exists below the expected utility equalising price.

When identifying the profit maximising point a search is made for local maxima in the profit function in both the inferior and superior ranges.[11] A comparison is made between the profit of any existing maximum and the profit obtained were the firm to undercut the expected utility of its opposition by an epsilon.

If the profit associated with an existing local maximum is greater than profit gained with undercutting the firm's profit function falls into either case (a) or case (d). Where the expected utility equalising price promotes a profit at least as great as at the local maximum cases (b) and

[11] A local maximum in the profit function occurs for most values of a competitor's price but will not always exist.

(c) are possible. Where no local maximum exists the optimum price is simply an epsilon below that which equalises expected utility and will be found in the search for a local maximum.

The optimum price referred to above constitutes one point on the reaction curve of the firm when plotted in conjunction with the competitor's price. To derive other points on the firm's reaction curve its competitor's price is varied and the procedure repeated.

V. SEARCH MODEL RESULTS

These examples all assume that the income loss due to illness (L) is half of income (m=10), search cost (k) is 0.1 and the shared marginal cost is 1. It is assumed that 1 million patients suffer from the illness treated by the drugs in the subgroup addressed.

(1) Two identically distributed drugs

Where $\lambda_1 = \lambda_2 = 1, \eta_1 = \eta_2 = 1$ the reaction function for firm 1 is given below.

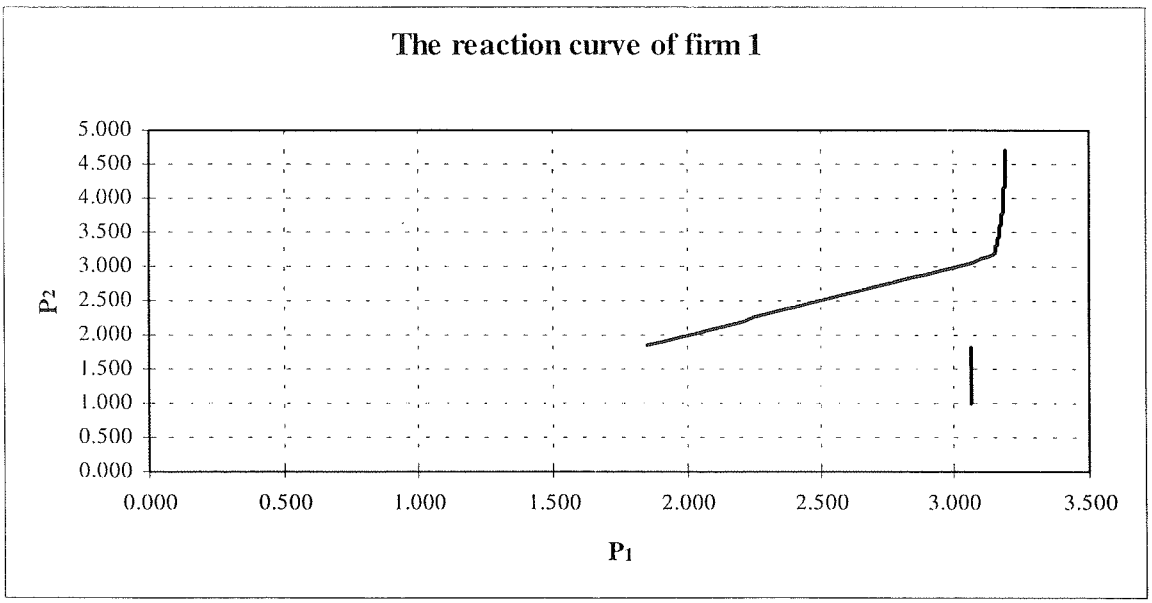


Figure 3.7: Reaction curve of firm 1 (identically distributed drugs).

For P_2 below 1.854 the reaction function is vertical. This is a vagary of the exponential function used for this model but is not particularly important.[12] Case (b) in Figure 3.5 displays the transition at approximately $P_2 = 1.854$ where the optimum decision for firm 1 changes from accepting inferior status to undercutting. The straight line until $P_2 = 3.15$ corresponds to undercutting behaviour. Where $P_2 \geq 3.15$ it becomes optimal for firm 1 to price below the level required to attain superior status.

Since the two firms are identical the reaction function of firm 2 is identical to that of firm 1 reflected through $P_1=P_2$. Figure 3.8 displays both these curves together.

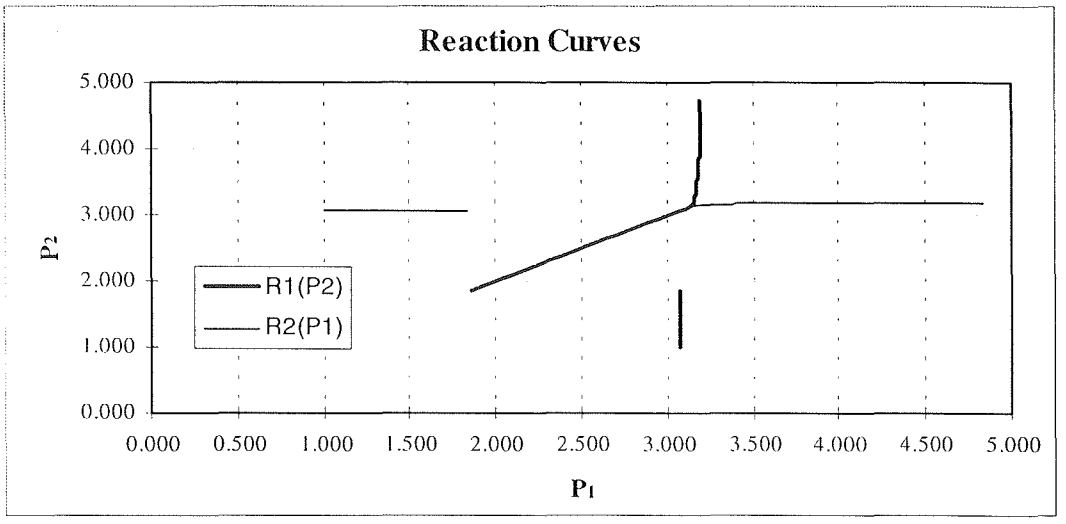


Figure 3.8: Reaction curves (identically distributed drugs).

At first glance it appears that a multiplicity of Nash equilibria occur. The region along which this the reaction curves appear to converge is however where both firms are attempting to undercut. The two reaction curves are therefore 2 epsilons apart throughout the range where the curves appear to touch. This non-intersection makes for an interesting dilemma as without a true intersection of the reaction curves no equilibrium in pure strategies exists.

Before proceeding to attempt to circumvent this non-existence problem it is wise to first examine how prevalently this phenomenon occurs. No equilibrium exists in this example because of the value accruing to whomever holds superior status. Superior status is available to both firms without either firm having to charge a large amount less than their competitor. The

[12] See Appendix 3.2 for an explanation of this phenomenon.

following sections attempt to examine different cases and discover whether this phenomenon is pervasive.

(2) A large difference in the efficacy of drugs

Here drug 1 is of a greater overall quality than drug 2 with $\eta_i = 1$ ($i = 1,2$) but $\lambda_1 = 1$ and $\lambda_2 = 0.5$. Obviously drug 1, with twice the efficacy of drug 2, is very likely to be superior once pricing decisions are made. Since the two firms are no longer identical each firm's reaction function is derived separately. Figure 3.9 displays the reaction curves for each firm.

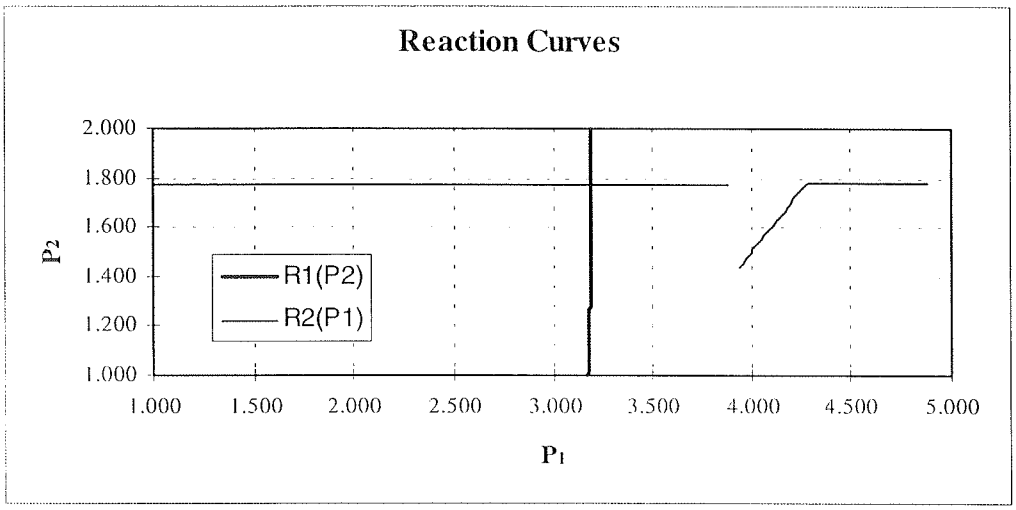


Figure 3.9:Reaction curves (asymmetry in efficacy).

The reaction curve for drug 2 is similar to that seen in the previous section. The leftmost portion corresponds to where the manufacturers of drug 2 present their drug as being inferior. The noticeably upward sloping portion (above $P_1 = 3.94$) corresponds to where drug 2 seeks to undercut the expected utility of drug 1 while the portion where $P_1 \geq 4.27$ corresponds to where the profit function has a global maximum where drug 2 is superior.

Drug 1 is superior along all of the points on its reaction curve. For drug 2 to attract a positive market share the price of drug 2 must be less than 2.5; otherwise no consumer would ever rationally select it. The decision rule for drug selection states that if a patient is to select a drug then $\lambda \geq \varphi > \frac{p}{L}$, or $p < \lambda L = 2.5$. A summary of the unique sequential search Nash equilibrium in prices appears in Table 3.1.

	Price (p)	Quantity (μ)	MC (c)	Profits (π)
Firm 1 (superior)	3.1903	0.3046 m	1.0000	0.6672
Firm 2 (inferior)	1.7692	0.0937 m	1.0000	0.0721
No treatment		0.6016 m		

Table 3.1: Nash Equilibrium (asymmetry in efficacy).

For smaller differences in efficacy (for example $\lambda_2 = 0.9$) no equilibrium in pure strategies exists.[13] For an equilibrium to occur there must be a very large asymmetry in efficacy between the firms.

(3) A large asymmetry in risk

This case involves a drug 1 with a greater overall quality than drug 2; $\lambda_1 = \lambda_2 = 1$ but $\eta_1 = 5$ and $\eta_2 = 1$. The difference in risk renders the mean side effect from drug 1 only one fifth as extreme as that of drug 2. Displayed in the below diagram are the reaction curves for this case.

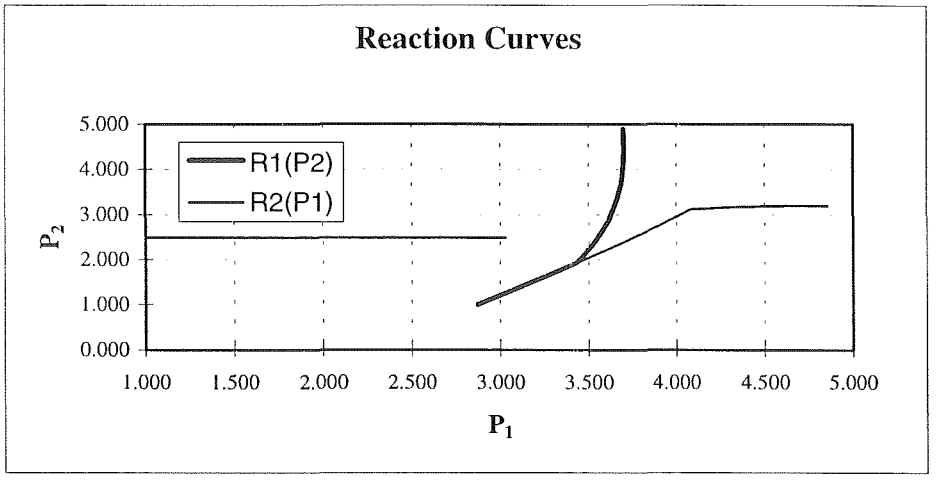


Figure 3.10: Reaction curves (asymmetry in risk).

The manufacturer of drug 1 attempts to reach either a local maximum as a superior drug (for $P_2 > 2.29$) or chooses to undercut (for $P_2 \leq 2.29$). Firm 2 accepts an inferior position for $P_1 < 3.05$ and undercuts until P_1 reaches approximately 3.90. The two reaction curves do not intersect and, as in the first case no equilibrium in pure strategies exists.

[13] See Appendix 3.3 for alternative scenarios with smaller values for efficacy.

(4) Balanced asymmetry

In this case the two drugs have similar expected utilities where they charge the same price. Drug 1 is characterised by $\lambda_1 = 0.85, \eta_1 = 1.1$ and drug 2 by $\lambda_2 = 0.90$ and $\eta_2 = 1$. Drug 1 is therefore less effective but provides a more secure option than drug 2.

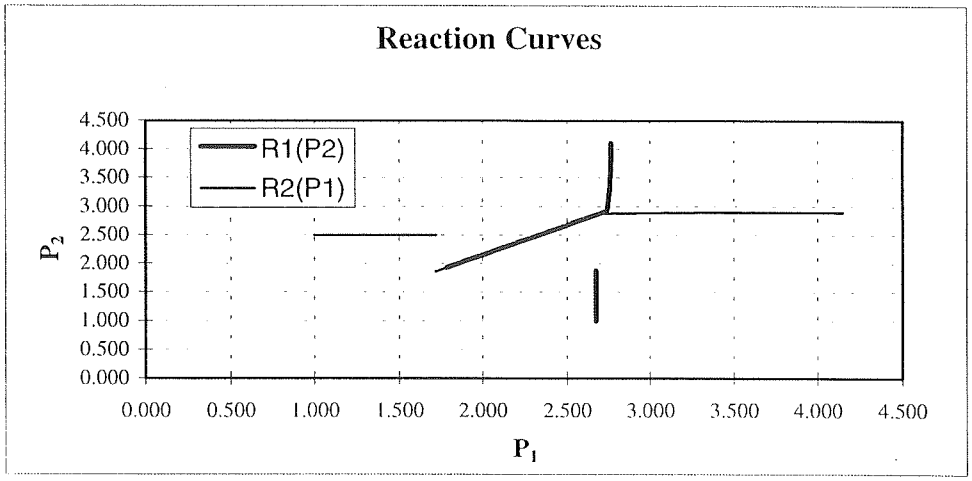


Figure 3.11: Reaction curves (balanced asymmetry).

Unfortunately the problem of non-existence seen in the first example appears pervasive. Since very little power can be attributed to any model where an equilibrium does not occur further action must be taken. The following chapters explore the problem of non-existence in the context of both historical modifications of the Hotelling model and a modification wherein the search component of this model is removed.

CHAPTER 4

RESOLVING THE NON-EXISTENCE PROBLEM

Where no equilibrium exists a model has very little predictive or explanatory power. In order to predict the effects of different regulatory regimes in the pharmaceutical market it is necessary to first resolve the problem of non-existence of an equilibrium in pure strategies.

In order to find a solution to the problem of non-existence three different methods are available to resolve the problem. A previously used Hotelling remedy may be applied to the problem, mixed strategies may be searched for or the model must have its search component removed. Chapter 3 included references to a general non-existence problem common to spatial models of Bertrand competition. This raises the possibility that a method previously used to resolve the Hotelling non-existence problem may aid the resolution of the non-existence problem faced in the pharmaceutical market model of Chapter 3. Krouse, in *Theory of industrial economics*,[1] defines the essence of this problem as follows:

> This failure of an equilibrium to exist is related directly to the abruptness of the demand change with mill price undercutting and the associated discontinuities in price reaction functions ... The non-existence problem can be "corrected" by alternative specifications of the model.

The general problem of such discontinuities in the demand and reaction functions of firms was observed to occur in the previous chapter. Alternative specifications of the Hotelling model addressed in Krouse include: using transport costs that are strictly convex in distance, restricting solution concepts to those where undercutting is impossible, allowing sequential entry into the market, and making relocation costs prohibitive. Modifications analogous to those used for the Hotelling model may prove effective in alleviating the non-existence problem in the pharmaceutical market model.

---

[1] Krouse, C. (1990) Theory of industrial economics. Blackwell, Massachsetts USA. p146.

I. CONNECTIONS BETWEEN THE PHARMACEUTICAL AND HOTELLING MODELS

The basic Hotelling model considers two vendors offering ice creams along a stretch of beach. Each seller chooses both their location and price. The pharmaceutical model outlined in Chapter 3 places two competing firms in a marketplace and allows them to set their prices. The link between prices in both markets is obvious.

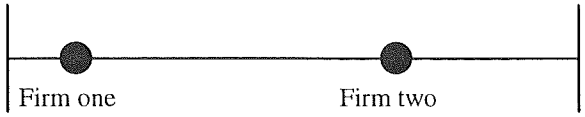


Figure 4.1: The Hotelling location model.

The Hotelling model assumes that consumers lie evenly along the length of the beach. This story of location is analogous to an assumption that the distribution of consumers is uniform along a line of length L. In the first stage of the model firms locate themselves somewhere along the line while in the second stage firms choose price. In the second stage of the game each consumer faces two options; either purchase from firm one or firm two. The prices faced by a consumer for the good produced by each firm are:

$$c_i = p_i + t\, l_i$$

where c_i is the cost of the good of firm i, p_i is the mill price of the good of firm i, t is the constant transportation cost and l_i is the distance of the consumer from firm i.

Each consumer chooses the cheapest of the two goods available. The marginal consumer is indifferent between the firms and so for this consumer $p_i + t\, l_i = p_j + t\, l_j$ and $l_j = l_i + (p_j - p_i)/t$. The following diagram displays the choice made by consumers based on the price and location decisions of firms.

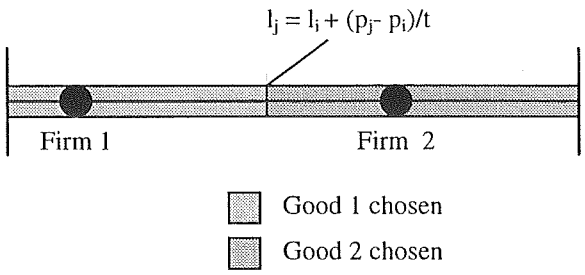


Figure 4.2: Choice in the Hotelling model.

Firms, predicting consumer choice, determine their optimum price based on location. Solving for the first stage of the game firms then select their location based on their beliefs about their competitor.

The pharmaceutical model differs from this approach since there are not one but two forms of location evident in the model through quality and expected utility. The characteristics a drug has with respect to the efficacy and risk of treatment define the first of these location concepts. The second form of location is the order of the firm in the search sequence, which is defined by expected utility and hence price. The superior drug is selected for treatment (without testing the inferior drug) for all patients for whom it promotes at least the expected utility of the inferior drug. Testing of the second drug occurs only if the superior drug does not promote the expected utility of drug 2. Where patients know the qualities of both drugs the treatment option selected will be that promoting the greatest level of utility. In this model there will also be those consumers who find that no drug is of sufficient quality to continue treatment.

Figure 4.3 highlights the decisions made by patients as to treatment under a sequential search framework where drug 1 has superior expected utility. The final decision made by any consumer is dependant on the values of quality faced.

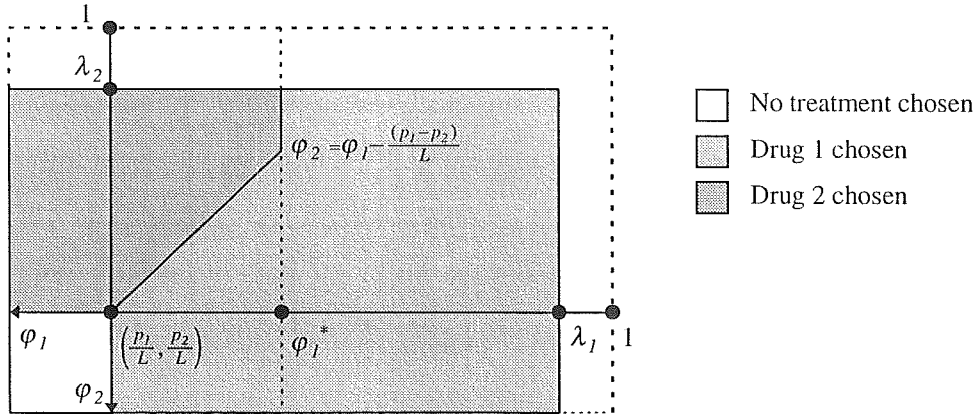


Figure 4.3: Choice in the pharmaceutical market model.

In the section where the patients ultimately discover the quality of both drugs ($\varphi_1 < \varphi_1^*$) the decision rule regarding drug choice has marginal consumers where $\varphi_2 = \varphi_1 - \frac{(p_1 - p_2)}{L}$ (or alternatively $p_2 = p_1 + (\varphi_2 - \varphi_1)/L$). This is very close to the definition of the marginal consumer under the Hotelling model. The closeness of definitions implicitly links the concepts of distance (Hotelling) and drug quality (pharmaceutical model) for at least some consumers. Likewise

transport cost corresponds to the loss due to an illness since they deflate the differences in distance and drug quality respectively. There does not appear to be an equivalent for expected utility in the Hotelling model as such an equivalent must depend on both the location and the price charged of both firms.

II. APPLYING HOTELLING MODIFICATIONS TO THE PHARMACEUTICAL MODEL

(1) Strictly convex transport costs

One method of alleviating non-existence of equilibria in the Hotelling model is to impose strictly increasing transport costs on the model.[2] Transport costs in the Hotelling model are analogous to the loss in income caused by illness in the no-treatment case. Where transport costs are strictly convex the modified Hotelling model promotes an equilibrium where firms take extreme positions on the line segment representing the market.

Unfortunately making the loss associated with no treatment dependant on product quality causes major complications. The natural definition of the loss function in such a case will be as a function of both drug qualities $L = L(\varphi_1, \varphi_2)$.[3]

Previously the loss from illness and the individual qualities patients faced were unrelated. With the addition of this relationship this is no longer the case. We know have a system of equations with one equation and three variables. Once the loss and the quality of the first drug is known the individual specific quality of the second drug can be derived. This eliminates both the need for search and the independence between drug qualities.

Adding an error term to the relationship between individual qualities[4] and the loss function prevents the derivation of one quality from the knowledge of the other. It does not however

---

[2] Lane, W. (1980) Product differentiation in a model with endogenous sequential entry. Bell Journal of Economics 11(1):237-60.

[3] Since this is analogous to making transport strictly convex in distance from the supplier.

[4] So that $L = L(\varphi_1, \varphi_2) + \xi$ where ξ is a random variable uncorrelated with either quality.

restore the independence of individual drug qualities since the knowledge of one quality still provides some information about the unknown quality.[5]

Of additional concern is the question of why L, as a variable valid whether or not treatment occurs should be related to a variable meaningful only if treatment occurs. If any relationship were to exist it would seem more reasonable to have quality[6] be a function of loss rather than the case necessary to apply this solution to the pharmaceutical market model. Even in such a case the problem of dependence would still arise between the loss and qualities. This solution to the Hotelling model does not appear to be a natural addition to the model and so is not an option to alleviate the non-existence problem.

(2) No-undercutting solutions

This section is motivated by a section of Krouse (1990) where he summarises the general results of Eaton and Lipsey (1978), Novshek (1980) and Carruthers (1981).[7] The basis of these results is an argument that price strategies should dismiss undercutting when firms have perfect foresight and constant marginal costs. The justification of this proposition appeals to the notion that neither firm can price their competitor out of the market For some region close to each firm's location it can charge a profitable price regardless of whatever cost covering price its competitor charges.[8]

The model presumes that firms, seeing this to be true, will never choose to undercut their competitors since they know they will not drive them from the market. Now for undercutting to be an optimal strategy all that is required is that expected profits are higher than when pricing at a local maximum. The modification of the normal Hotelling model addressed here uses *modified zero conjectural variations* in order to prevent undercutting on the part of firms. These conjectures postulate that undercutting will never be successful because any attempt to undercut by a firm provokes an equivalent change in the price of its competitor.

---

[5] Since the relationship allows for the derivation of a distribution for the second quality.

[6] Which is the proportional decrease in lost income in income due to treatment.

[7] For references to Eaton and Lipsey (1978), Novshek (1980) and Carruthers (1981) see the bibliography.

[8] See Appendix 4.1 for proof of this proposition.

This conjectural variation model, as with all models of its type, attempts to model quasi-dynamic behaviour by introducing a limited form of reaction into a static model. By modifying the normal Nash equilibrium concept these models attempt to integrate the immediate reaction of a firm to the actions taken by their competitor. The problem with this form of model is that it only takes two stages into account; it provides no reason why the original mover would not move in response to the reaction of their competitor. In this modified model there is no reason why the original mover is unable to undercut the lower price charged by their competitor in the second stage and gain an increased portion of the market.

By restricting quasi-dynamic behaviour introduced into the model to only two stages any power the model may have to predict outcomes will necessarily suffer from less than true dynamic outcomes. This modification has very little relevance in the Hotelling model and no more in resolving the problems of non-existence in the pharmaceutical model explored here.

(3) Sequential location and immobility

One major problem associated with the classical Hotelling model is that it assumes that firms can freely adjust their location. In product differentiation models this assumption is often highly unrealistic as changing the essential characteristics of a brand is difficult and in the case of pharmaceuticals effectively impossible. The costs of relocation are many and varied and include research and development, advertising, changes in the way goods are produced, and the cost of redesigning a product. For markets where these costs are likely to be large enough to pose a serious impediment to moving it seems reasonable to make location a once-and-for-all decision. In the pharmaceutical market model the decision of drug characteristics is left to nature.

Firms acknowledge the permanence of their location when entering the market. Decisions on location consider the positions of both current firms and likely entrants. This type of modification to the general framework is of little use when applied to the pharmaceutical market model. The pharmaceutical model already incorporates immobility of firms concerning the characteristics of drug quality. The alternative location concept in the pharmaceutical model is that of the position in the search sequence which unfortunately is itself a function of price. Any restrictions on expected utility also restricts the ability of firms to choose their price. No further

restrictions on the choice of location are possible in the pharmaceutical model and so this solution to the non-existence problem is not relevant here.

Examples of this modification in the Hotelling model quoted in Krouse (1990) include Hay, D (Sequential entry and entry deterring strategies in spatial competition. *Oxford Economic Papers* 1976:240-57.) and Lane, W (Product differentiation in a model with endogenous sequential entry. *Bell Journal of Economics* 1980:237-60).

(4) The Salop circle model

One of the most important modifications of the Hotelling model is the circle model developed by Salop (1979)[9]. Instead of considering firms who locate along a line segment the Salop model has ice-cream sellers locating along a circle. This circle is formed by joining the endpoints of the line segment in the Hotelling model. The Salop model also incorporates an outside option into the market. Such an option is already a feature of the pharmaceutical market model here as patients face a choice not only of which drug they prefer for use in treatment but also whether or not to accept treatment.

Before proceeding in the definition of the Salop model it is pertinent to pause and examine what a circular model would imply about the market for pharmaceuticals. Recall that consumers are located in two quality dimensions. Where location is represented by the pair (φ_1,φ_2) the extreme points of the plane in which patients lie are at $\{(-\infty,-\infty),(-\infty,\lambda_2),(\lambda_1,-\infty),(\lambda_1,\lambda_2)\}$. An approximation of this plane is given in Figure 4.4. In order to form a circle the Salop model joins the endpoints of the normal Hotelling line segment. In order to form an equivalent to the circle of the Salop model here the endpoints of the patient plane have to be joined. Three options are available to do this: pairs of corners could be joined and a hollow cylinder formed or all four corners of the patient plane could be joined. Where all four corners are joined either a sphere or a torus is formed.

[9] Salop, S. Monopolistic Competition with Outside Goods. (1979) Bell Journal of Economics 10(1):141-156.

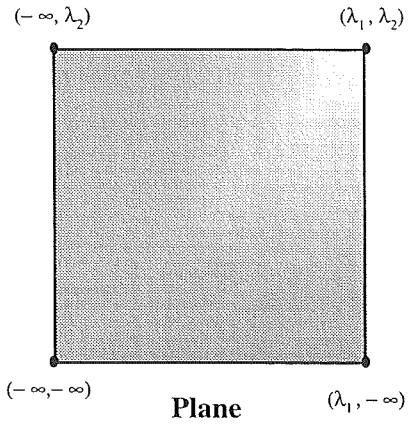


Figure 4.4: The patient plane.

In order to join points it must hold that consumers at the joined points exhibit the characteristics of both all the combined points. In the case of the cylindrical view in Figure 4.4 the patient plane has been joined along the top and bottom edges. This join implies an implicit assumption that, for drug 2, consumers facing a quality of the drug so poor as to cause instantaneous death are also those that face no side effects from treatment. As death can be construed as a considerable side effect this is obviously not the case.[10]

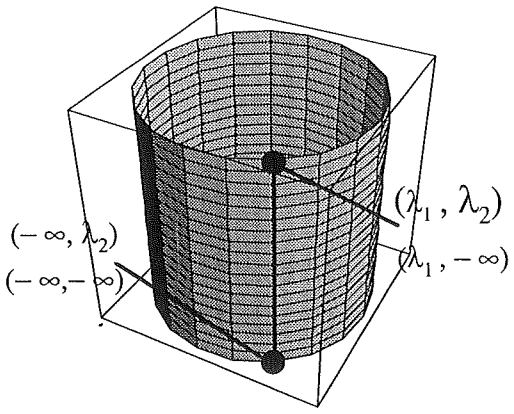


Figure 4.5: Cylindrical modification of the patient plane

Figure 4.6 considers both the cases where all four corners are joined at one point. Here an implicit assumption is made that consumers who face a quality of a drug poor enough to cause

[10] Had the join in the model been made along the left and right edges of the plane the same problem would occur but this time for drug 1.

instantaneous death are also those that face no side effects from that drug. This assumption again is trivially false.

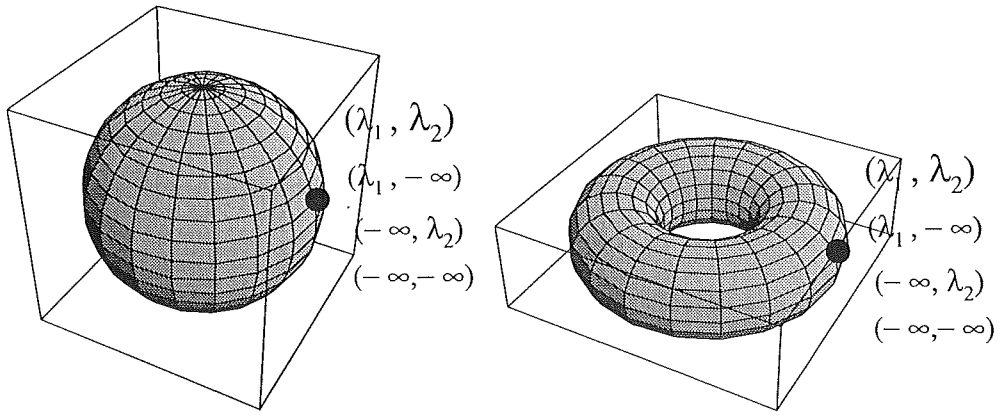


Figure 4.6: Sphere and torus versions of the patient plane.

While it is a reasonably innocuous assumption to say that the preferences of the two extreme consumers with respect to ice cream are equivalent this will not be the case for the individual specific qualities of pharmaceuticals. The modifications made to the Hotelling model in order to form the Salop circle model work well in that setting but can not be applied to the pharmaceutical market model in order to alleviate the non-existence problem.

III. THE NON-EXISTENCE PROBLEM

Non-existence of Nash equilibria in pure strategies occurs in this game because of a discontinuity in the reaction function of each firm. The discontinuity occurs where the profit associated with a successful undercutting of a competitor's expected utility coincides with the profit associated with accepting the status of an inferior drug. The interruption in the reaction curve thus occurs at the point where the optimal mode of behaviour of a firm changes. The level of prices corresponding to undercutting and inferior pricing will differ. Undercutting behaviour promotes a drug to superior status while if a drug is inferior its price must be in excess of the level that equalises expected utility. With these prices falling either side of the price equalising expected utility the two must be different.

The problem of non-existence is then inexorably tied into the sequential search character of the model. It is this facet of the pharmaceutical model that requires different modes of behaviour to occur for firms.

Although much has been done here to attempt to circumvent the problem of non-existence the problem nevertheless appears intractable. In order to force equilibria to exist in this market either the search component of the model must be removed or a search must take place for mixed strategy equilibria. The difficulty of establishing the existence of mixed strategy equilibria and the likely complexity in calculation for mixed strategies make this an awkward choice; either to greatly complicate the model or remove possibly important behaviour. If the no-search model produces pricing outcomes not too dissimilar from prices (or price ranges, in the case of non-existent equilibria) predicted by the search model then the risk of removing important behaviour appears low. Chapter 5 addresses the model without search behaviour and attempts to evaluate how close the prediction of each scenario is to the original model.[11]

---

[11] While it is hoped that mixed strategies exist in the pharmaceutical market model this by no means certain. The problems of a non upper semi-continuous profit function (effectively a profit function which takes a downward jump) are well known (see Fudenberg, D. and Tirole, J. (1992) Game Theory. MIT Press. p.485). In this case the assumptions of most general existence proofs fail to hold. Existence proofs that do not require upper semi-continuity (for example Dasgupta, P and Maskin, E. (1986) The existence of equilibrium in discontinuous economic games. 1: Theory. *Review of Economic Studies* 53:27-42.) rely on results being established as to the actual properties of the profit function. Proving that, as would be required, the sum of payoffs is upper semi-continuous is likely to be time consuming (given that numerical calculations appear to be required to find mixed strategies in games approximating the main game).

Upper semi-continuity of the sum of payoffs does hold for the Hotelling model but the non-uniform nature of probability in the pharmaceutical market model means that this result does not automatically hold here. Recall that the problem in the pharmaceutical market model was not with a firm's location in the sense of a point on the patient plane but rather with its place in the search order.

These factors necessitate a large amount of work in simply proving the existence of a mixed strategy equilibrium without consideration of the costs of calculating equilibria once the model becomes more complex under reference pricing and alternative subsidisation schemes.

In addition to the problem of defining Nash equilibria over mixed strategies is the debate over their practical application. An example of this is in Osborne and Rubinstein (1994) where each takes an opposing position on whether or not mixed strategies are used in reality.

CHAPTER 5

THE NO SEARCH MODEL OF THE PHARMACEUTICAL MARKET

In recreating the pharmaceutical market model without search behaviour the assumptions adopted correspond closely to those outlined in Chapters 2 and 3. The basic framework of drug quality, quantity and price remain similar when considering both patient and producer choice.

I. PATIENT CHOICE IN A NO SEARCH SETTING

Patient choice in the no search setting may differ from the earlier setting in two ways; different assumptions are made regarding consumers and the decision process of patients has changed. Sections 1 and 2 outline these changes.

(1) Changes in the assumptions regarding patients

After the removal of sequential search many assumptions of Chapter 2 may either no longer be necessary or may require modification. Fortunately the majority of the assumptions adopted in Chapter 2 are retained without change. The individual specific quality of a drug is once more assumed to follow an exponential distribution. Individual specific qualities are again assumed to be independent. The form of the budget equation changes slightly with search costs no longer featuring in the model while utility remains a function of available consumption.

$$U_{ij} = y_{ij}$$

$$p_i q_{ij} + y_{ij} = m - L(1-\varphi_{ij}\sqrt{q_{ij}}),$$

$$U_{ij} = m - p_i q_{ij} - L(1-\varphi_{ij}\sqrt{q_{ij}}).$$

The decision rule between drugs where their qualities are known by an individual remains the same, as does the restriction of quantity to a binary choice.

$$q_{ij} = \begin{cases} 0 & if\ \varphi_{ij} \le \frac{p_i}{L} \\ 1 & if\ \varphi_{ij} > \frac{p_i}{L} \end{cases}$$

The restrictive intertemporal assumptions made in the sequential search case may now be substantially relaxed. Each individual knows the qualities they face of each drug in each period. As long as those suffering both new or recurring illnesses are distributed independently along the side effects distribution an exponential distribution may be used to represent the population of all patients. Information in the modified framework is perfect so there is no possibility for two identical patients[1] to choose different drugs because no patient has superior information. This possibility, which will now not occur, was a potential source of bias in the sequential search framework. The possibility of bias necessitated assumption of an infinite population and that no illness could last longer than a single period. These assumptions are discarded since they represent restrictions that are no longer necessary.

Where searching forms an important part of a model the expectations parties have over the characteristics of different products are important. In the pharmaceutical market model once search is removed the expectations of both doctors and patients become irrelevant as perfect and costless information is available.

(2) Changes in patient choice

It is now assumed that every patient either knows the qualities of each drug option they face.[2] The precise mechanics of how drug quality is discovered is no longer of any significance as far as influencing consumption is concerned. The diagram below was used to display the decisions made in the sequential search framework where drug 1 is superior.

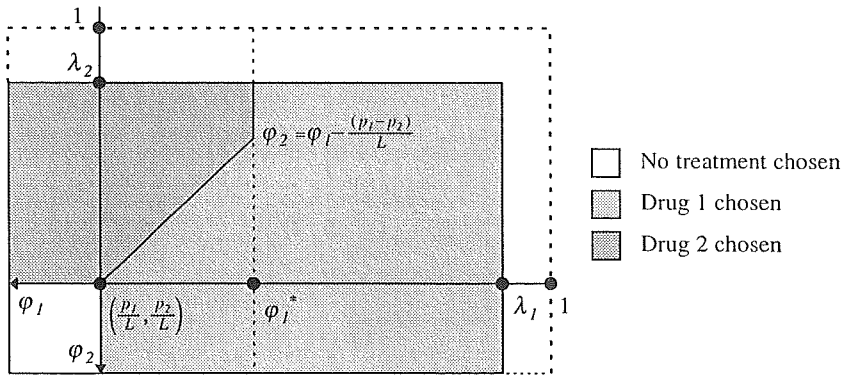


Figure 5.1: Choice in the pharmaceutical market model.

[1] Patients facing identical side effects.

[2] Alternatively it could be assumed that drugs may be sampled costlessly and simultaneously.

The search component of the model is represented in the above diagram by the change in consumer behaviour around φ_1^*. Where drug 1 has a quality above φ_1^* it will be selected regardless of the actual quality of drug 2. For values of quality below the search threshold the patient tests the quality of drug 2 and makes her decision based on the true qualities of each drug. The threshold value of quality, φ_1^* is used to determine whether or not a patient will choose to discover the value of φ_2.

In the no search setting the value of φ_2 is costlessly available and so will be known by all patients when making their final treatment decision. The line representing marginal consumers ($\varphi_1 - \varphi_2 = \frac{(p_1-p_2)}{L}$) is continued through φ_1^* until it reaches the edge of the box to create a Figure 5.2.

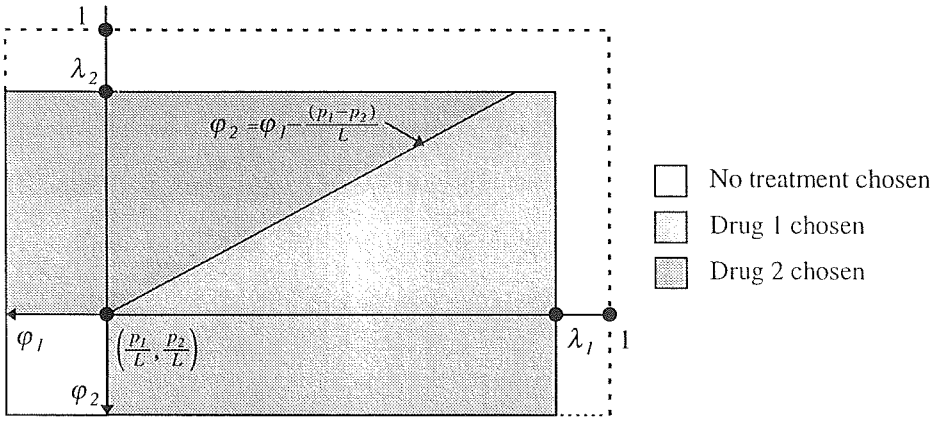


Figure 5.2: Choice in the pharmaceutical market model (full information).

The decision each consumer makes is given in a tabular form below.

	$\varphi_2 \leq \frac{p_2}{L}$	$\varphi_2 > \frac{p_2}{L}$
$\varphi_1 \leq \frac{p_1}{L}$	No drugs are purchased	Drug 2 is purchased
$\varphi_1 > \frac{p_1}{L}$	Drug 1 is purchased	Drug 1 is chosen if $\varphi_1 > \varphi_2 + \frac{(p_1-p_2)}{L}$ Drug 2 is chosen if $\varphi_2 \geq \varphi_1 - \frac{(p_1-p_2)}{L}$

Table 5.1: Choice in the pharmaceutical market model.

The market share of each drug is derived in Appendix 5.1 and is displayed below:

$$\mu_1 = \begin{cases} \int_{\frac{p_1}{L}}^{\lambda_1} f_1(\varphi_1) F_2(\varphi_1 - \frac{(p_1 - p_2)}{L}) d\varphi_1 & \text{if} \quad \lambda_1 - \frac{(p_1 - p_2)}{L} \le \lambda_2 \\ 1 - F_1(\lambda_2 + \frac{(p_1 - p_2)}{L}) + \int_{\frac{p_1}{L}}^{\lambda_2 + \frac{(p_1 - p_2)}{L}} f_1(\varphi_1) F_2(\varphi_1 - \frac{(p_1 - p_2)}{L}) d\varphi_1 & \text{if} \quad \lambda_1 - \frac{(p_1 - p_2)}{L} > \lambda_2 \end{cases}$$

$$\mu_2 = \begin{cases} \int_{\frac{p_2}{L}}^{\lambda_2} f_2(\varphi_2) F_1(\varphi_2 + \frac{(p_1 - p_2)}{L}) d\varphi_2 & \text{if} \quad \lambda_2 + \frac{(p_1 - p_2)}{L} \le \lambda_1 \\ 1 - F_1(\lambda_1 - \frac{(p_1 - p_2)}{L}) + \int_{\frac{p_2}{L}}^{\lambda_1 - \frac{(p_1 - p_2)}{L}} f_2(\varphi_2) F_1(\varphi_2 + \frac{(p_1 - p_2)}{L}) d\varphi_2 & \text{if} \quad \lambda_2 + \frac{(p_1 - p_2)}{L} > \lambda_1 \end{cases}$$

$$\mu_{ND} = F_1(\tfrac{p_1}{L}) F_2(\tfrac{p_2}{L})$$

where $f_i(\bullet)$ and $F_i(\bullet)$ are the probability and cumulative density function for the distribution of the quality for drug *i*.

The number of patients selecting to take no treatment has not changed from that observed under the search framework. In the search framework all patients selecting no treatment had previously explored all drug options and so had full information in the search case when making their final decision. Not surprisingly those choosing not to take any treatment in the search case will do so in the non-search case also. Those choosing to take some treatment under the search case will again have at least one available option better than no treatment.

II. PRODUCER CHOICE UNDER THE NO SEARCH FRAMEWORK

As with patient choice the majority of the assumptions used in Chapter 3 continue to hold in the absence of sequential search. Producers are assumed to be rational profit maximisers who compete on the basis of price alone. As with the previous framework quality competition does not occur and product differentiation naturally results from the framework for patient choice. Constant marginal costs are adopted once more in order to maintain consistency with the earlier framework and to aid computation. The total number of patients is again assumed to be one million.

The choices made by firms no longer hinge on whether a price accords them superior status and so the profit function of firms is now a continuous function, an example of which is given in Figure 5.3.

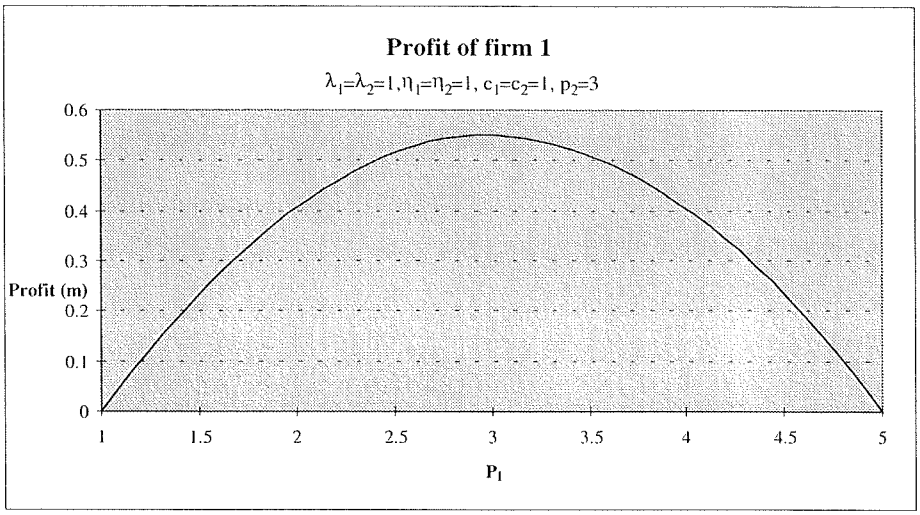


Figure 5.3: Sample profit function.

With this continuous profit function the local maximum is the only point of interest when deriving the reaction function of the firm in question. By Rolle's Theorem[3] a local maximum must exist for some price greater than marginal cost since:

(1) profit where $p_i = c_i$ is zero (zero profit per unit)

(2) profit at $p_i = \lambda L$ is zero (zero consumption)

(3) the profit function is continuous and differentiable.

The reaction function of each firm can therefore be found by searching for this local maximum for varying values of the competitor's price.

III. COMPARISONS BETWEEN SEARCH AND NO SEARCH RESULTS

The no search framework will be used in the remainder of this thesis only if the results it obtains are not too dissimilar to those predicted by the search model. Comparing the results

---

[3] Rolle's theorem is a generalisation of the Mean Value Theorem which states that "If f is continuous on [a , b] and differentiable on (a, b), and f(a)=f(b), then there is a number x in (a, b) such that f'(x)=0". Spivak, M. (1980) *Calculus*. Houston TX, Publish or Perish, Inc. 2nd edition. p.178.

obtained by both the search and no search models is complicated by the frequent non-existence of equilibria in the former. As a result of this difficulty the comparison breaks down to a comparison of the predicted prices of each model. Where the predicted prices are similar the allocative efficiency and profits of the firms should be approximately equal.

When comparing the following cases the values m = 10, L = 5, k = 0.1 and $c_1 = c_2 = 1$ are used for income, loss and marginal costs respectively.

(1) Two identically distributed drugs

Here the assumptions $\lambda_1 = \lambda_2 = 1, \eta_1 = \eta_2 = 1$ are carried over from the search case. The search case predicts that no equilibrium will exist but that prices will generally lie where undercutting is the dominant behaviour for each firm. The joint undercutting section is represented by a shaded area in Figure 5.1. The no search reaction curves and the resulting equilibrium are also displayed.

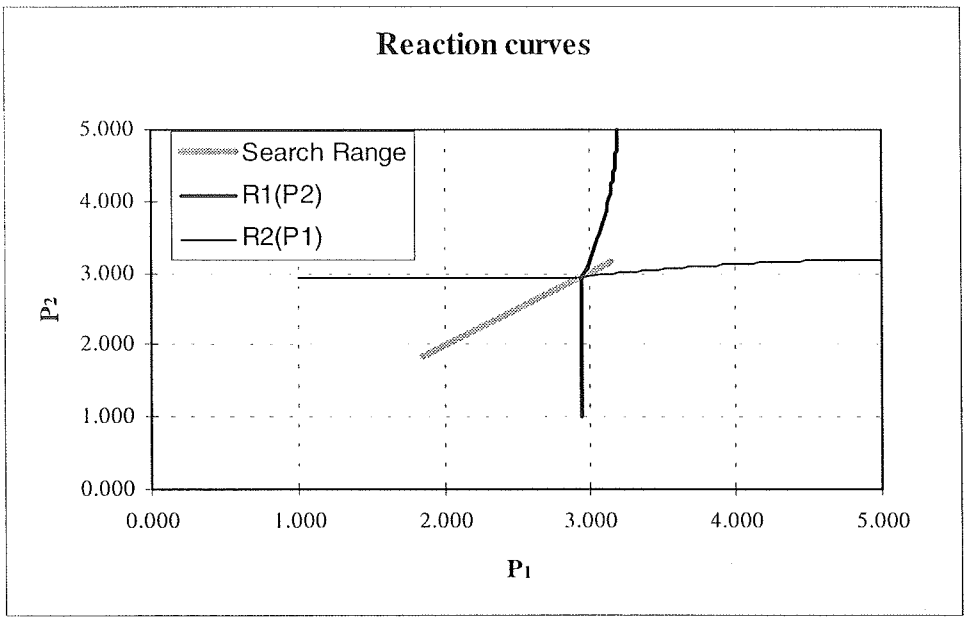


Figure 5.4: The search and no search models (identically distributed drugs).

The equilibrium resulting from two identically characterised drugs falls in the general area predicted by the search model. Not surprisingly this equilibrium involves each firm charging an identical price (at 2.95). That the equilibrium lies in the area predicted by the search model

suggests that in this case transferring to a no search model will not be too costly in terms of lost accuracy.

(2) A large difference in the efficacy of drugs

As with the earlier analogue to this case $\eta_i = 1$, $\lambda_1 = 1$, and $\lambda_2 = 0.5$. The search model promoted a unique Nash equilibrium in prices for this case. The reaction curves in the no search case are plotted below in addition to the point suggested by the search equilibrium.

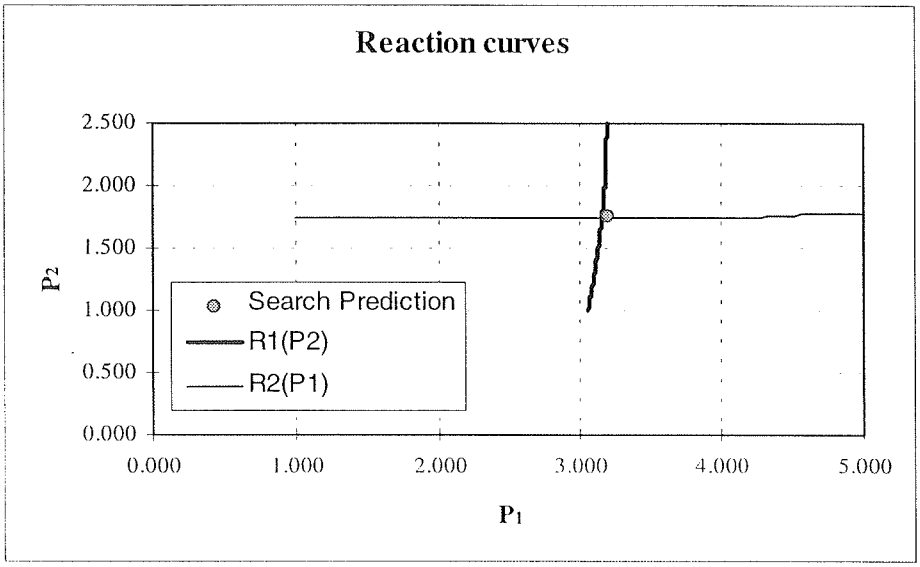


Figure 5.5: The search and no search models (asymmetry in efficacy).

In the case of a large difference in the efficacy of drugs the search model predicts an outcome where p_1=3.19 and p_2=1.76. The no search model predicts a unique equilibrium in prices will exist where p_1=3.15 and p_2=1.74. The two predictions are very close suggesting that the two models provide nearly equivalent results.

(3) A large difference in the risk of drugs

This case assumes that $\lambda_1 = \lambda_2 = 1$ but $\eta_1 = 5$ and $\eta_2 = 1$ so that drug 1 has on average only 20% of the side effect of drug 2. In this case the search model predicts that no equilibrium will exist in pure strategies. The range of prices suggested by undercutting is again represented on the diagram below by the shaded area. The reaction curves of each firm under the no search case are also displayed.

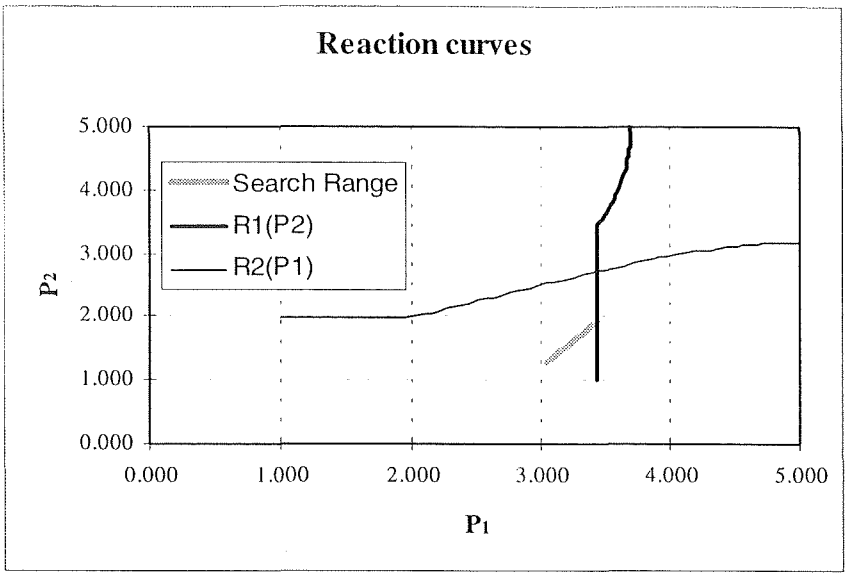


Figure 5.6: The search and no search models (asymmetry in risk).

The shaded region is a reasonable distance from the outcome predicted by the search model and involves higher prices for both firms. The predictions of the two models although in the same vicinity, are not as close as other cases. This may be a result of the very large nature of this asymmetry in this case.

(4) Balanced asymmetries between drugs

In this case the two drugs have similar expected utilities where the same price is charged. Drug 1 is characterised by $\lambda_1 = 0.85, \eta_1 = 1.1$ and drug 2 by $\lambda_2 = 0.90$ and $\eta_2 = 1$. The sequential search framework predicts that, as with the majority of cases, no pure strategy Nash equilibrium exists. The no search framework again predicts that a unique Nash equilibrium exists in the pharmaceutical market. Figure 5.7 below displays the reaction curves under the no search framework while the shaded area represents the range predicted by the pharmaceutical market model.

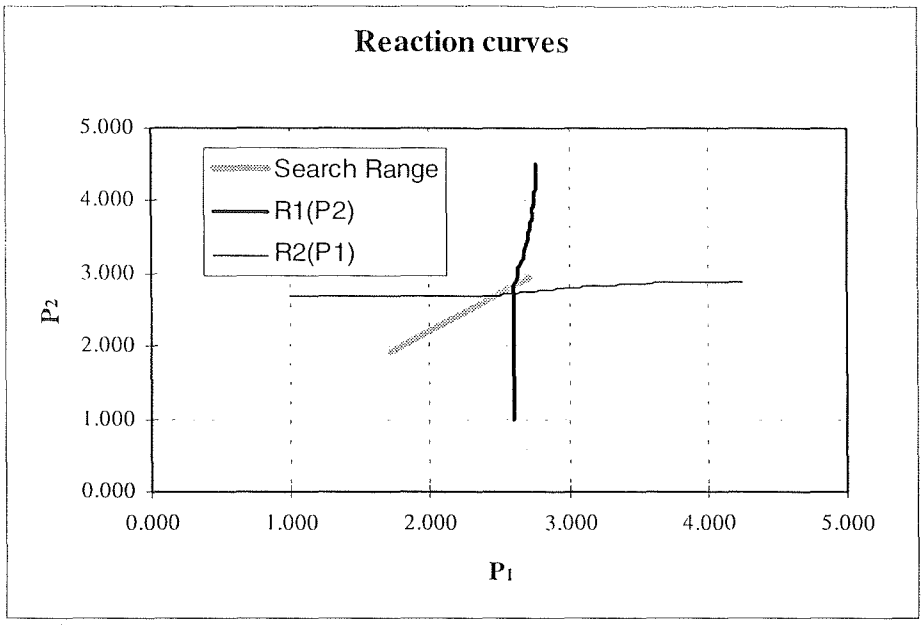


Figure 5.7: The search and no search models (balanced asymmetry).

The unique Nash equilibrium here falls very close to the predictions of the search based model.

In general there appears to be little lost in transferring from a search to a non-search framework. The non-search framework is sufficiently complex to give a reasonable approximation to real life while giving results that can be interpreted. Now that the pharmaceutical market model has been modified it now has a pure strategy equilibrium. With the removal of the search from the decision making process profit functions no longer suffer from a violation of upper semi-continuity and so pure strategy equilibria are guaranteed.[4] The modified model now allows for investigation of issues relevant to reference pricing. The following chapter examines reference pricing and compares the outcomes found there to those found under the unregulated duopoly case explored here. Chapter 7 compares reference pricing to an alternative scheme that is possibly superior to both an unregulated duopoly and reference pricing in a perfect information framework. Chapter 10 extends this comparison into a world where marginal costs are unknown.

[4] Dasgupta, P. and Maskin, E. (1986) The existence of equilibrium in discontinuous economic games. 1: Theory. *Review of Economic Studies* 53. pp 27-42.

CHAPTER 6

REFERENCE PRICING

Reference pricing is used internationally to limit the cost of pharmaceuticals. A reference price is an upper limit on the amount an insurer or a governmental agency will pay for a group of drugs deemed to be equivalent.[1] Where firms charge at or below the reference price patients pay nothing towards the cost of the drugs except the fees intermediate agents may charge.[2] If a price is set above the reference price patients will incur the difference between the price received by the drug company and reference price.[3] Prices above the reference price are restricted by consumer demand since the higher is the producer price the larger is price a patient must pay.[4] Prices below the reimbursement level are lightly restricted by demand since an increased price for a drug priced below the reference price will generally result in an increased reference price and a corresponding decrease in the patient price of all other substitute drugs.

Pharmac, the agency given the responsibility for setting drug subsidies in New Zealand, explains reference pricing in the following way:[5]

> Reference pricing is based on the classification of pharmaceuticals into different therapeutic groups and further into subgroups. The classifications are defined as:
>
> - *A therapeutic group* - a set of pharmaceuticals which are used to treat the same or similar condition(s)
> - *A subgroup* - a set of pharmaceuticals which produce the same or similar therapeutic effect in treating the same or similar condition(s)

In New Zealand the reference price is set at the level of the lowest priced good. Overseas the reference price is set in many different ways. Germany's reference price is computed as the average of the prices of that drug and similar products. In Sweden, the reference price is set at

---

[1] The strength of 'equivalence' varies between countries with some countries categorising groups of drugs that have the same or similar therapeutic effect and some restricting groups to all drugs with the same active ingredients.

[2] Drug wholesalers, pharmacists and the government are the most likely intermediaries. The charges these parties place on pharmaceuticals are generally ignored in this analysis.

[3] Minus any additional margins and taxes applied to these drugs.

[4] Since the patient pays the difference between the producer price and the reimbursement level.

[5] Kletchko S.L. and others. (1995) *Targeting Medicines, Rationalising Resources in New Zealand; A preliminary paper.* Wellington, Pharmac. 26p.

10% above the price of the least expensive generic equivalent to the drug. The situations where a reference price exist differ in all three countries: New Zealand has a reference price in most therapeutic subgroups, in Germany several drugs are necessary in any subgroup for a reference price to be used and lastly, in Sweden a generic equivalent must be available in the market for reference pricing to be applied. Where reference prices do not exist either the manufacturer's price is paid by the sickness fund (Germany), or the government negotiates prices with the manufacturers (Sweden).[6]

I. THE INTERNATIONAL SUCCESS OF REFERENCE PRICING

The majority of the evidence presented here is sourced from a 1995 report by Joseph Zammit-Lucia and Rana Dasgupta (RD). Titled *Reference Pricing: The European Experience*[7] this report attempted to analyse the effects of European reference pricing systems in light of a decision by the Italian Government to adopt a reference pricing framework. They found that price controls in their various guises do not generally achieve their aim of restricting the growth in pharmaceutical expenditure.[8]

With the exception of Greece, ZD found that every country considered saw their pharmaceutical expenditures grow more quickly than the general price level. This is unsurprising since the quality of available pharmaceuticals has increased over time. Increased quality drugs are likely to attract higher prices and be suitable for more patients, forcing expenditures to grow faster than inflation. Demographic factors are also likely to bias this comparison with an ageing population demanding increased medical care.

Zammit-Lucia and Dasgupta examined the more interesting comparison of the relative rates of growth of pharmaceutical and total healthcare expenditures. Because the growth in total health expenditures includes both inflationary, demographic, and general health quality measures

---

[6] *International Pharmaceutical Spending Controls: France, Germany, Sweden and the United Kingdom.* Health Care Financing Review, Spring, 1994

[7] Zammit-Lucia, J and Dasgupta, R. *Reference Pricing: The European Experience.*1995, 31p. (St. Mary's Hospital Medical School, University of London, Health Policy Review no. 10)

[8] Forms of price controls include those allowing firms to price a certain level above marginal costs, and those using international price comparisons to limit reimbursement, in addition to reference pricing,

it is likely to provide a better measure of the relative rate of growth of pharmaceutical expenditures. ZD conclude that countries with price controls tend to have had less success in controlling the relative growth in pharmaceutical expenditures than those who do not have such controls. The relative ineffectiveness of schemes concentrating on supply-side measures are isolated and this difference was attributed to demand-side factors including:

(i) Increasing prices: price increases occur even in schemes specifically targeting such increases.

(ii) Substitution towards newer, more expensive therapies: it is inevitable that patients will be drawn to higher quality treatments (which tend to be more expensive to the taxpayer) if the prices to the patient of both treatments are similar. Where the aim of a regulatory system is to keep consumer prices low for all treatments it is unsurprising that this becomes an imposing problem.

(iii) Increased overall demand: with an ageing and/or growing population the call for pharmaceuticals priced at constant levels will inevitably rise.

Price controls fail to influence the factors driving the increase in overall demand. Countries adopting demand-side measures (in favour of the supply-side) were said to have enjoyed a greater degree of success.

Zammit-Lucia and Dasgupta were critical of reference pricing since it is claimed that it discriminates against poorer patients. Those patients responding adversely against reference priced products but not to their alternatives may have to pay a premium for treatment. Limitations in income may be a decisive factor in the final determination of medical treatment. Patients who would otherwise have gained the same benefit from treatment are unable to do so because of a lack of access to the treatment that best suits them.

The German experience, where reference pricing scheme was introduced on 1 September 1989, attracts the most attention from Zammit-Lucia and Dasgupta. From 1987-1988 pharmaceutical expenditures grew by 7.7%. With the threat and subsequent introduction of reference pricing expenditures grew only by 0.9% in the year to December 1989. This rate of growth did not continue in the years following with rates of 7.8%, 11.8% and 7.2% observed in the years to 1990,1991 and 1992 respectively. It was concluded that reference pricing has, at

best, only a short term effect and in the longer term is completely ineffective.[9] This ineffectiveness was attributed to the relatively minor role price plays in the increase of pharmaceutical expenditure. Without consideration of volume and prescribing structure expenditures will continue to grow at a brisk rate.

ZD claimed that substitution took place towards products not covered by the reference pricing system. The reason for this is unclear and appears to be based on promotional changes on the part of the pharmaceutical companies. It was observed that reference pricing led firms to switch promotional effort to non-reference priced drugs which in turn led to large changes in consumption patterns. This appears rational only if the non-referenced priced subgroups were heavily subsidised by the government.

In Sweden the introduction of reference pricing does not appear to have had a noticeable effect. In the year following introduction growth fell by 1.6% and in the year following that increased 2.1% to reach its highest ever growth level at 15.8%.

Denmark introduced reference pricing after a period of reform in the pharmaceutical industry. An exemption system differentiates Denmark from most schemes with doctors able to apply for their patients to be made exempt from reference pricing provisions. The year reference pricing was introduced the growth in pharmaceutical expenditures fell. Whether this was due to reference pricing or a complementary ban on non-reference priced products is uncertain. As observed in other countries growth began to increase to former levels after the initial introduction of reference pricing.

The Netherlands introduced a reference pricing system that has substantial differences from the standard scheme. Reference pricing is generally applied where two or more 'therapeutically equivalent' treatments exist. This naturally limits the number of markets in which reference pricing is applicable. The Netherlands attempted to circumvent this problem by defining subgroups not as therapeutically equivalent drugs but as wider 'clusters'. Although attempts were made to avoid problems inherent in the German scheme the results achieved were just as unspectacular.

---

[9] Available and relevant data is no longer available on the German pharmaceutical market since, post-unification, the characteristics of the country have changed markedly.

Zammit-Lucia and Dasgupta were highly critical of reference pricing, basing their beliefs on its failure to contain costs in the medium and long terms, its discriminatory nature, its sphere of influence and its potential to encourage inefficiencies.

II. THE SUCCESS OF THE NEW ZEALAND SYSTEM

As with all forms of regulation there are divergent opinions about the success of reference pricing in New Zealand. The following subsections explore the claims made by Pharmac as well as other interested parties in New Zealand.

(1) Claims made by Pharmac

In *Pharmac: the first 20 months* Pharmac claims that:[10]

> "Reference pricing is highly effective. It reduces the excessive market segmentation based on brand marketing that allowed suppliers to establish markets that were free from price competition."

Pharmac does not identify this 'excessive market segmentation' or the way in which reference pricing alleviates this problem. This phrase appears to suggest that Pharmac believes different drugs are close to identical in all respects but differentiated only by the expectation of doctors. It is difficult to comprehend how imposing a pricing scheme on to the pharmaceutical market will alleviate such a problem. The formation of brand loyalty for doctors is rationally a result of the information they have, which is largely provided by experience, their peers and the drug companies. There does not appear to be any reason why drug companies will generally change the information they give to doctors as a result of reference pricing.[11] Indeed the only reason this information will change is if a firm exits the market as a result of reference pricing. An exit would be detrimental to patient welfare if the drug represented a significant alternative to other drugs for even a few patients.

---

[10] Pharmaceutical Management Agency Limited. *Pharmac: the first 20 months,* Wellington, Pharmac 1995. p 10.

[11] The phenomenon observed by Zammit-Lucia and Dasgupta is a possibility but not one that helps Pharmac's case here. Where drug companies decide to transfer advertising into non-reference priced groups 'excessive market segmentation based on brand marketing' will still exist, albeit in a different location.

The only source of new information implicitly provided by the reference pricing scheme is the composition of therapeutic subgroups. If Pharmac is to be believed there is little or no difference between the drugs comprising each subgroup. If this was the case then no pervasive differences in price would be observed and the reference priced drug would typically be the only treatment taken. In actuality large differences in price can, and do exist within subgroups of drugs that are supposed to be interchangeable. In the antihistamines group for the active ingredient Ketotifen there are two alternative drugs, Zasten and Asmafen. These drugs are considered to be interchangeable multi-source medicines (IMM) so that no difference is expected for any patient if they were switched from one to the other. For such identical drugs it is expected that they will both have the same supplier price. For the 1 mg per 5 ml oral liquid preparation Asmafen costs $5.55 for a 200 ml bottle. For exactly the same sized bottle at exactly the same preparation Zasten costs $15.68. The price of Zasten is 283% of the price of Asmafen.[12] The conclusion that drugs within subgroups may be differentiated in some form appears to be clear cut.[13] Non IMM drugs can also differences in price; in the "Infections - Agents for Systemic Use/Antibacterials/Macrolides and Aminoglycosides" both Erythromycin Ethyl Succinate and Erythromycin Stearate have treatments subsidised at $22.29. 100 Erythromycin Stearate (brand name ERA, 250 mg) tablets cost $25.20 while 100 tablets of Erythromycin Ethyl Succinate (brand name E-mycin, 400 mg) tablets cost $22.29.

The only alternative explanation for price differences is that doctors continue to be convinced of differences where none in fact occur. This possibility, while not impossible, appears unlikely given that doctors will know the quality of least some of the alternatives available to patients within a subgroup. Although small price differentials may have their origins in reputation only it stretches credibility to claim that differences in prices of over 150% have no basis in fact.

Pharmac appears to expect prices within subgroups to fall to the level of the reference priced product. This occurs naturally where two drugs have exactly the same pharmacological

---

[12] Source: December 1997 Pharmaceutical Schedule as listed on Pharmac website (http://www.pharmac.govt.nz/).

[13] Either as independently distributed drugs or as drugs with the types of asymmetries covered in the Chapter 8.

effect for all patients. In this case the firms have identical products and if both firms have the same marginal cost, reference pricing will result in both firms charging at marginal cost.[14] At first glance this appears to be a consequence of reference pricing. An unregulated situation would also predict exactly the same outcome as reference pricing here. The favourable outcome is not a result of reference pricing but is instead a result of Bertrand competition (over producer prices) with homogenous products. Any system where reducing price below that of all competitors gives a firm the lowest consumer price (and the entire quantity demanded at that price) will result in exactly the same behaviour. In this case reference pricing will promote an outcome where price is shared and driven to marginal cost because only here will doctors perform as Pharmac desires and prescribe only the cheapest drug in every therapeutic subgroup.

Pharmac expects prices to tend to fall to match the reference price since it expects that all drugs in a therapeutic subgroup are the same or similar for patients. If differences in quality do exist then Pharmac appears to believe that drugs should still match the reference price. If one drug has a greater overall quality to another it is expected that it will gain a greater price which reflects its superior nature. For a superior drug to be denied a premium price appears to damage a firm's incentive to produce a higher quality product.

In a Parliamentary question of 10 June 1997 it was claimed that Pharmac had saved $78 m to July 1996. It was stated that a further $100 m was expected in savings by June 1997.[15] This claim is based on an extrapolation of past trends in pharmaceutical consumption in New Zealand. The savings were claimed to have come from encouraging price competition and through a review of the terms and conditions of subsidy of products already on the Pharmaceutical Schedule.

Pharmac has also claimed that from 1993-1995 they reduced the rate of growth in pharmaceutical expenditure to around 7% per year down from the 11%. Pharmac appears to give very sketchy details of the origin of this 11% figure but it is likely that this comes from

---

[14] Both firms play the simple Bertrand game outlined in Chapter 4 here.

[15] http://www.newsroom.co.nz/stories/HL9706/S00021.htm

Ministry of Health forecasts.[16] Whether there was, and is, room for further improvement is one of the major questions addressed by this thesis.

Pharmac claim that from 1993 to 1995 the number of subsidised prescriptions increased by eight per cent. Pharmac also claim that in some areas, such as epilepsy, herpes, and asthma, reference pricing has allowed for the treatment of many more people because of more liberal access to some drugs. It is uncertain whether the composition of drugs consumed have changed; a drastic change may indicate the introduction of lower quality drugs. Pharmac appear to believe that drugs in a therapeutic sub-group are the same or similar and so that the actual quantity use of each drug will have bearing on health effects. Consistent with this view Pharmac does not appear to consider any possible health effects from the system of reference pricing in its published results.[17] Unfortunately where the effects of changes in the health regime are not studied a vital facet of the efficacy of the health system is completely ignored. Studies on the effects reference pricing on patients may be worthwhile in confirming Pharmac's hypothesis that the drugs are similar. Conversely Pharmac may consider that it is better not to know what the health effects of its policies are. If drugs within the same sub-group are found to be significantly different Pharmac will face significant pressure to re-list many expensive drugs in separate sub-groups.

Pharmac appears to discount published reports on the efficacy of new drugs to a degree. The reasons for this are stated in the following quote by David Moore:[18]

> Much of the trial research for new drugs is financed by the manufacturer. If the results are not favourable to the drug, chances are the trial results do not see the light of day. The corollary is that often only favourable results get published. An American study in 1994 of published results of trials on nonsteroidal anti-inflammatory drugs (NSAIDs) in the treatment of arthritis concluded: "The manufacturer-associated NSAID is almost always reported as being equal or superior in efficacy and toxicity to the comparison drug. These claims of superiority,

---

[16] A diagram on page seven of Pharmac: the first 20 months displays historical costs and forecasts of pharmaceutical expenditure. The sources for this graph are given as Health Benefits Ltd data and Ministry of Health forecasts.

[17] It is not clear what information Pharmac receives with regard to usage of different drugs or, indeed what information they seek. It may be that Pharmac is not in a position to report changes in quantities but this does not necessarily restrict them. The health effects of reference pricing on health outcomes can be judged, in part, by the costs imposed on services dependant on failures in medication. For example cholesterol lowering agents may be judged, in part, by the level of heart attacks of patients using drugs in the relevant sub-group.

[18] http://www.pharmac.govt.nz/drugscene/ds_corol.htm

> especially in regard to side effect profiles, are often not supported by trial data. These data raise concerns about selective publication or biased interpretation of results in manufacturer-associated trials.

Pharmac is likely to be correct in being cautious about the validity of figures quoted by drug companies but must be careful to still consider all available evidence. The drug trials are both costly and time consuming and if Pharmac chooses not to accept data provided by drug companies it must rely on either experience from other countries regarding drugs (which may also be 'tainted' by drug companies) or must run its own studies. The alternative is that Pharmac makes decisions without the benefit of information over the relative effectiveness and safety of drugs. Deciding whether a drug represents a therapeutically equivalent or superior option to existing treatments is likely to be at the very least a challenging proposition with very little information to base the decision on.

Pharmac has been vocal on the subject of its relationship with the drug companies. As a small agency it claims that it needs to be tough to compete with the lobbyists of the pharmaceutical giants. This relationship was characterised as "healthy tension" by Mr Moore. [19] In the appearance of David Moore before the health select committee he claimed that such tension is still necessary on the basis that some medicines are available in New Zealand at a higher price than in either Australia or Britain.[20]

In summary Pharmac has claimed that:

> In an environment of capped health care budgets, Pharmac has done well for the health care of New Zealanders. It is an achievement that many countries with health care systems partly- or wholly-funded from the public purse would like to emulate.[21]

The early success so far of Pharmac's regime has seen several countries, including Australia research the reference pricing scheme adopted here. The limited adoption of a reference pricing scheme was announced in the last Australian Budget. This is puzzling given Pharmac's statements that prices in New Zealand are greater than those observed under the

---

[19] Hunt, G *National Business Review* 30/5/97 p9

[20] Hunt, G *National Business Review* 30/5/97 p9

[21] http://www.pharmac.govt.nz/page_2.htm

current Australian scheme.

(2) Woodfield, Fountain and Borren (1997)

Woodfield, Fountain and Borren[22] provide examples of where the actions of Pharmac do not necessarily reflect their stated decision criteria. They also criticise the system of reference pricing, finding that it has several qualities that promote undesirable outcomes in the pharmaceutical market. The following quote reflects the former of these criticisms:

> In practice, however, Pharmac also apparently engages in the following policy, provision for which is not explicitly covered in its Operating Policies and Procedures Manual. This policy appears to involve refusing to list a new drug in a therapeutic sub-group unless its price is reduced to that of the currently reference -priced product. It also appears that Pharmac may permit a new drug to enter at the reference pricing (although no higher than this) if the supplier is willing to make other concessions such as reducing its price of one or more of its other lines. In the latter case , this may have the implication of reducing the subsidy paid to all drugs in a particular therapeutic sub-group.

The case of Naprosyn, which will be addressed later (p 72) was also cited as a possible example of Pharmac's actual procedures differing from those published at Pharmac's inception.

Pharmac is criticised for labelling as inappropriate the targeting methods of restrictions by outlet, cost and quantity. A section of the report from Kletchko, Moore and Jones is reproduced below in order give an accurate view of Pharmac's policies:[23]

Influencing user behaviour

Users can be influenced by price signals such as:

- a percentage co-payment system - rejected in New Zealand in the past because of concerns about patient access
- non-price barriers - those currently in place in New Zealand are:
  - restriction by outlet (e.g. pharmaceutical must be dispensed at hospital pharmacy)
  - restriction by cost (e.g. the patient must pay extra for the drug)
  - restriction by quantity (e.g. maximum of one month's supply)

---

[22] Woodfield, A. and others. (1997) Money & Medicines: An Economic Analysis of Reference Pricing and Related Public-sector Cost-containment Systems for Pharmaceuticals with Special Reference to New Zealand. Auckland, Merck Sharp & Dohme (New Zealand) Limited. 271p.

[23] Kletcho, S.L. and others. (1995) p.24.

> These are very blunt targeting tools but they do fulfil the technical efficiency criteria very well. For example, hospital pharmacy dispensing usually lowers demand, but it is unclear whether or not patients receiving treatment should be doing so and vice versa.
>
> Restriction by cost is particularly poor in terms of the equity criteria, as patients receive treatment according to their ability to pay, rather than clinical benefit.

Given the problems facing the Pharmac it is curious that the above avenues should be discounted. The percentage co-payment system may have been rejected in the past but that does not necessarily make it an inferior scheme to reference pricing which may itself be rejected in the future. The essence of an effective co-payment scheme is that it must levy greater costs to a patient for more expensive treatments. A capped limit on co-payments may achieve a greater level of patient access (while reducing the effectiveness of the scheme) but this does not appear to have been considered.

While scorn is poured on any scheme that imposes a positive price for pharmaceuticals on the grounds of equity and patient access there is little mention of positive prices under reference pricing. Positive prices with their origins in quality differences may exist and, as with the co-payment scheme and restriction by cost it may well be the case that patients may receive higher quality drugs according to their ability to pay.

The non-price barriers listed above as 'currently in place' are strangely incomplete. Missing from their number are some of Pharmac's tactics which appear a little more arbitrary than those named by KMJ. Given that cost[24] is not to be a consideration for doctors any meaningful restriction of pharmaceutical costs must necessarily use quantity restrictions. These 'appropriate' quantity restrictions are highlighted by the comments of Dr Paul Shillito. Dr Shillito is a pediatric neurologist who publicly complained at the restrictions he faced when treating children with epilepsy in the Christchurch Press of 2 September 1995:

> New anti-epilepsy drugs were available that could help those children but they were expensive and pediatricians were not able to use them enough. The Government restrictions on the two most commonly used of the new drugs meant Dr Shillito could only prescribe them to 13 of his patients.
> 'One-third of the children I see have epilepsy, and in 15 per cent of those it is intractable and I can only prescribe to 13 children.' Dr Shillito said.

---

[24] By which Pharmac appears to mean the price to the taxpayer rather than the marginal cost of production.

Dr Shillito continued, stating that doctors knew which drugs could help children but were not able to prescribe them. Alternative drugs for these children had been tried but had either not worked or had intolerable side effects. Pharmac's actions in restricting subsidies by setting quantity at a level below required treatments appears a little more blunt than setting, for example, a restriction on the number of pills that be placed in a bottle. For Pharmac's treatment quotas to be effective in reducing subsidisation there is no alternative but to set these quotas below the number of people who potentially could benefit from the use of the drug. On equity grounds this appears more worrying than any of the measures listed above.

(a) Substitution towards expensive alternatives:

An interesting case highlighted by Woodfield *et al* outlines a possible problem with reference pricing. Suppose drugs A, B and C can all be used to treat a particular illness. Drug A is both more costly and more effective than drugs B and C in terms of its side effect profile. Drug A is assumed to fall into a different therapeutic subgroup where it is the only drug (and so also the reference priced drug). Drugs B and C occupy the same therapeutic subgroup with drug B dominating the cheaper drug C. Drugs A and C, being reference drugs, attract either low or zero prices while the price of drug B is higher. Some patients, suffering an adverse side effect from both A and C, will choose to use drug B. The majority of patients, facing a choice of two low priced drugs will select drug A. Some of these patients would no doubt have chosen either drugs B or C had the true cost of the drugs been levied directly. This represents a source of inefficiency in decision making which directly increases the cost of pharmaceuticals. There is no incentive for patients to select the cheaper option when drug A is available at a low (or zero) price.

Suppose otherwise that drug A is not listed on the pharmaceutical benefits schedule. Patients then face a heavily subsidised drug C, a drug B which attracts a small part charge, and an expensive drug A. Patients suffering from adverse reactions from drugs B and C face a large price for treatment (through drug A) for no other reason than their reactions to the listed drugs. This appears to be a significant penalty to patients for no reason other than the quirk of fate determining that they face a large side effect. In either of these cases those facing an adverse reaction to drugs A and C are likewise disadvantaged

Suppose that Pharmac faces a situation where drugs B and C are established in the marketplace within the same therapeutic subgroup and A is a drug applying for listing on the Pharmaceutical Schedule. Woodfield *et al* propose that Pharmac then have the option of either listing drug A in a separate subgroup or rejecting an application for its listing. If the listing takes place drug A will attract a large portion of the market and, being expensive, cost the taxpayer a large sum of money. Unless the company producing drug A makes hefty concessions to Pharmac it is likely that drug A will not be listed in its own subgroup.

If drug A was listed it would have the same patient price as drug C, giving no incentive to patients to choose the cheaper of the drugs. There are no significant incentives produced by reference pricing in this case to suggest that patients will select the cheaper drug. If nothing is done to counter this problem Woodfield *et al* correctly suggest that patients will be selectively discriminated against for no reason but their misfortune to not to react favourably to the cheapest drugs on offer. Patients who react favourably to the cheapest drugs do however benefit from the public provision of drugs. As both types of patients pay for treatment indirectly this generates a transfer of wealth from those who react unfavourably with inexpensive drugs to those who do not.

Pharmac may recognise that drug A is an important treatment option for patients and wish to see it subsidised. If it was to list drug A in the same subgroup as drugs B and C it would secure a superior budgetary outcome. In listing drug A along with drugs B and C Pharmac inherently claims that there is no significant therapeutic difference between the three. Drug A is available to patients at a cheaper rate than would have occurred had it not been listed. With the addition of drug A into the subgroup it is reasonable to assume that the prices of B and C will not rise. Pharmac will have to pay (at most) the same amount as before per treatment. Treatment levels may rise slightly with an extra subsidised alternative available to patients but costs are unlikely to blow out to the degree seen in the case where drug A is subsidised in its own subgroup. This option appears to be, at least in the short term, a better avenue for Pharmac than either listing drug A in its own subgroup or refusing to list it at all. For this reason this thesis allows drugs that are essentially different[25] to exist in the same therapeutic subgroup for the purposes of reference pricing.

---

[25] 'Essentially different' is taken to mean that the outcomes of at least some drugs are independent. While in reality complete independence will not occur it is simpler for modelling purposes to address

If Pharmac chooses to list innovative pharmaceuticals along with lesser, pre-existing options it does so at the peril of losing credibility. Pharmac, in listing drugs this way, would make a statement that the drugs are equivalent. Where physicians and the public perceive that drugs are different Pharmac runs the risk of being seen to be uncaring. The difficulty in this is that drugs that are in fact equivalent may still be seen to be different by the public and physicians due to the reputational effects. Even if physicians do not believe Pharmac's assertions that the drugs are equivalent the same subsidy is paid by the HFA for these pharmaceuticals. Unless public disenchantment with Pharmac grows to the level where government intervention is likely Pharmac does not unduly suffer even if it loses credibility.

In addition to the possible tactic identified above of listing superior drugs in subgroups along with lower quality drugs there is the potential that an inferior drug may be inserted into a subgroup in order to reduce subsidy payments.

(b) Reference pricing and the integrity of the patent system

The claim that reference pricing represents a *de facto* attack on the patent system is examined by Woodfield *et al.* The patent system attempts to provide the correct incentives for innovators by making sure that innovation is a profitable activity. For the required level of profit to occur the innovating firm must be in a position to charge substantially above marginal cost. Where low priced rival drugs are already in the marketplace firms may be forced to price at or below the reference price in order to obtain a place on the Pharmaceutical Schedule. At such low prices it may not be possible to make the requisite profits to make innovation an optimal choice if a sufficient portion of the international community regulates their pharmaceutical markets using reference pricing.

The problem of blockbuster drugs was also addressed. In the cases where drugs represent sufficient progress to warrant a separate subgroup it is not at all certain that listing will take place. Such a drug will be free to charge a very high price in the knowledge that its patient price

---

only complete independence and dependence between drugs. The alternative is to generalise to the full spectrum between total dependence (the quality of drugs are related by a one-to-one function) and total independence. The model used is already complex and the addition of varying degrees of dependence would pose a considerable hurdle. See Chapter 8 for an illustration of the difficulty of incorporating a pair of perfectly dependant options with one independent option.

will be low and a large volume will be sought. Pharmac, given the choice of whether or not to list this drug may decide not to on the basis of this large cost.[26] Particularly beneficial treatments might not reach the public of New Zealand as a direct consequence of the scheme of reference pricing.

(c) The problem of symmetric drugs

Woodfield *et al* identify a serious problem with the incentives of producers where both firms have identical demand and cost functions. If both firms receive the same subsidy and charge the same price it is possible that there will always be an incentive for either firm to increase price if it expects the other firm to join it. Suppose the firms initially charge equal prices and one firm increases its price. The firm that remains reference priced faces the choice of where to set its price in response. If it does not react it achieves a higher quantity given that its competitor now charges a higher patient price. Profits would thus increase in the case where it does not change its price.

If the firm increases its price to the level of its competitor's price it has the same patient price as it did earlier. As the firm increased its price the reference price (as the price of the lowest price drug in the subgroup) increased also. The firms have returned to the original situation but now make increased profits. The taxpayer must ultimately pay for the increased profits of the drug companies here. As long as each firm's own-price elasticity is less than unity it does not pay to undercut the current reference price.[27] Woodfield *et al* claim that, where the temporary change in price is discounted, the level of prices observed will continue to climb without bound. Here firms tacitly collude on the understanding that their competitor will always choose to match a higher price.

Pharmac must respond to this problem in some way. The method employed by Pharmac appears to be that it will relax the HFA's policy of having one fully subsidised drug in every

---

[26] Although there are good examples of the entry of such drugs. Prozac is clearly a blockbuster drug and Pharmac listed it, albeit with heavy restrictions. Initially only specialists could prescribe Prozac but it was released to general practitioners only after Eli Lilly agreed to reimburse the RHAs for Prozac prescriptions above $13.2 million from mid-1996 to mid1997. In more marginal cases Pharmac may either decide not to list for purely budgetary reasons or to list the drug in an existing subgroup.

[27] Inelastic demand is a sufficient rather than a necessary condition for unprofitable undercutting.

therapeutic subgroup when the reference priced drug attempts to increase its price. Woodfield *et al* attribute this behaviour as a possible explanation for the actions of Pharmac in its dealings with Roche. Roche attempted to increase the price of one of its lines of Naprosyn, a reference priced product. Pharmac (at least initially) declined to adjust its subsidy rate in line with the increased price of Naprosyn. Where the reference price is set below the level of the lowest priced drugs all drugs must have a positive patient price.

The problems of high subsidy payments under reference pricing are not restricted to cases where tacit collusion or oligopolistic interdependence promote a series of price increases. If firms are able to achieve high initial rates of subsidisation we may never see price increases just firms matching a high reference price.

Where products with non-symmetric linear demands were considered by Woodfield *et al* a similar, although bounded result was obtained. It was postulated that a reason for any high producer prices (and subsidy rates) was that the agency may have been wasting some of its strategic advantage by failing to force firms to compete for the right to be subsidised.

Woodfield *et al* proceed to criticise Pharmac on the following grounds:

(i) That its (unofficial) policy of demanding generic firms agree to generate a sequence of 30%, 20% and 10% reductions in scheduled prices may constitute a legal barrier to entry.

(ii) Because of the nature of reference pricing firms entering the pharmaceutical markets may decline to apply for listing on the Pharmaceutical Schedule.

(iii) Reference pricing may see the reintroduction of older drugs which have disappeared from the market due to obsolescence, having lower efficacy, or having more pronounced side effects.

(iv) Criticism over the characterisation of drugs into therapeutic groups and subgroups. This criticism was linked to the fact that drugs in different subgroups may be used to treat the same illness.

(v) Pharmac's reference pricing policy may itself be a deterrent to generic entry.

(vi) An alternative scheme, used by Australia in the 1980s, may be superior to reference pricing since it forces producers to compete for subsidies. Whether or not this scheme costs less while still promoting high levels of treatment is the major thrust of this thesis.

(3) The views of the pharmaceutical industry

The relationship between the pharmaceutical companies and Pharmac has not been an amicable one. There is naturally tension between Pharmac, whose task is to keep pharmaceutical spending to a minimum[28] and the drug companies, who naturally wish to see large volumes of drugs purchased at high producer prices. The animosity between these parties is best displayed by the volume of litigation before the courts. These cases prompted comments by David Moore before the health select committee that the drug companies were 'trigger happy' and 'sued on rumour'.[29]

The Chief Executive of the Researched Medicines Industry Association (RMI), Kim Miles has publicly stated his views on the way the pharmaceutical budget is prepared. In a September 1997 press statement he states:[30]

> It is time to review Pharmac's decision-making processes, to ensure patients are its main focus and an adequate budget is available.
>
> Pharmac prides itself in its role as cost-cutter and we entirely agree it should be looking at all of its options. However, it is first and foremost an agency of the Transitional Health Authority, the body charged with ensuring the nation's health. It must be time for its focus to be changed to patient welfare.

Pharmac currently exceeds its budget when primarily acting as a cost-containing agency. It appears reasonable to assume it would do so also as a welfare focused agency. Costs are likely to grow as currently marginal decisions are likely to lead to subsidisation if welfare rather than cost is targeted. For Pharmac to act as a more welfare orientated agency it must have a greater budget. Pharmac, with an increased budget is likely to allow greater use of expensive treatments currently available only from specialists. Loosening such restrictions would allow a greater quantity of high value drugs to be used, benefiting the companies producing these drugs. A greater budget is also likely to mean greater profits for the drug companies as Pharmac may not need to be as forceful in negotiations. The concern shown by the HFA over the budget deficits of Pharmac makes a greater budget (and so a greater welfare focus) unlikely.

---

[28] Subject to the reasonable pharmaceutical needs of New Zealanders being met.

[29] See NZPA 29 May 1997 *Pharmac Grilled on Confrontational Stance.*

[30] Researched Medicines Industry Association; *What is behind the latest prophecy of doom from Pharmac?* Press release of 2 September 1997. See http://www.nzhealth.co.nz/rmi/press/rel2sep.html

In a release coinciding with the 1996 election the RMI detailed an 'industry perspective'. In this the need to contain public expenditure on pharmaceuticals is acknowledged but it is claimed that there must be greater recognition of the benefits and value of modern medicines. The salient points the RMI wished to see in health policy included were the following:[31]

- The pivotal role medicines have in achieving high-quality, cost-effective care for all New Zealanders
- Greater focus on the good health outcomes pharmaceuticals can deliver, as against the current emphasis on cost containment
- The role of research and development in producing innovative medicines that improve health outcomes, and the impact this has on the price of medicines
- The shift away from secondary towards primary care health services and the resultant increased prescribing of pharmaceuticals
- The right of New Zealanders to have access to new, innovative medicines that improve health and can save costs in other parts of the health system like hospitals
- The impact of targeting and risk-sharing policies on the right to medicines access
- The impact of Pharmac's reference pricing policies on the ability of pharmaceutical companies to gain fair prices in New Zealand.

The RMI propose that a Pharmaceutical Advisory Group be established whose task would be to contribute towards the development of national strategies for the purchase and provision of pharmaceuticals.[32] The advantage of such a group, in the view of the RMI, is that it would 'assist in forging a greater synthesis and unity amongst the many participants in the pharmaceutical and wider health sector in the pursuit of agreed upon common goals.' This would be in direct comparison to the 'exclusive, divisive and combative' approach of Pharmac.

(4) The views of the wider medical community

Understandably, as with the drug companies, the wider medical community wishes to see the widest range of drugs available to treat illnesses. Predictably the majority of claims by the wider medical community are generally negative for this reason. Lobbyists of several medical groups including the AIDS Foundation, the Schizophrenia Fellowship and the Asthma Foundation have all attacked Pharmac at varying times, complaining about the lack of availability of drugs they see as vital to the health and well-being of New Zealanders.[33]

---

[31] Researched Medicines Industry; *The Political Parties and Pharmaceuticals - A Critical Analysis. Pharmissues* October 1996. See http://www.nzhealth.co.nz/rmi/press/issoct96.html

[32] Researched Medicines Industry Association; *Pharmaceutical advisory group proposed. Pharmissues* September 1997. See http://www.nzhealth.co.nz/rmi/press/isssep97.html

[33] See *The Press* of 21 December 1996 (p4), 29 September 1995 (p21), 25 April 1995 (p21)

The Medical Association also expressed concern that some patients may be denied the use of life-saving drugs because of budgetary constraints. Dr Brian Lineham, the chairman of the Association expressed concern that Pharmac may promote the use of cheaper, generic brands which may not be as safe or effective as other makes. Dr Lineham also stated that the blow-out observed in the pharmaceutical budget is the inevitable result of the expansion in new drugs which can tackle formerly untreatable diseases.[34]

There is no denying the difficult role Pharmac have to play in the subsidisation of drugs. However it appears that very few non-Pharmac sources are in agreement that the reference pricing system we have in place provides New Zealanders with appropriate pharmaceutical choices.

(5) Evidence from New Zealand's pharmaceutical industry

Pharmac inherited an industry where, they claim, the underlying growth in pharmaceutical subsidies averaged 11% per annum. From its formation in July 1993 Pharmac has attempted to greatly reduce the growth rate. The objective originally adopted by for Pharmac was to reduce growth in the level of drug spending to zero. While Pharmac appears happy with the savings accomplished in New Zealand doubts were raised in its 1996 report over the sustainability of the current rate of growth.[35]

> At present our drug subsidy bill is about $700 million a year - a small fraction of the $30 billion the government redistributes each year. The problem is that this fraction grows relentlessly despite efforts to contain it. Prior to PHARMAC the fraction was doubling about every seven years. PHARMAC has managed - not without controversy - to slow that down to a growth rate that would double the cost about every 10-12 years. Even at this rate of growth, by the time a baby born today reaches the end of an average life, the bill will rise to about $25 billion. Even after adjusting for inflation it is clear that the conflict we now have between taxpayers and health care consumers will, at some point in the future, escalate.

---

[34] Cited from TVNZ webpage http://www.tvone.co.nz/news Mon. Sep 15 07:05 1997

[35] Pharmaceutical Management Agency Limited (1996) *Annual Report 1996*. Wellington, Pharmac. p.11.

Predictably the Researched Medicines Industry Association (RMI) perceive the statistics differently:[36]

> According to data from the Ministry of Health, Pharmac and Statistics New Zealand, nominal government expenditure from 1987 to 1996 has grown by 57 percent - or at an average rate of 4.7 percent per year. However once the data are adjusted for inflation, the growth has been 7.1 per cent - or an average rate of only 0.7 percent per annum. Once the effects of population growth have been taken into account, it is apparent that real government expenditure on pharmaceuticals has actually declined.
>
> In 1987 real government expenditure on pharmaceuticals per capita was $197.42. In 1996 this had fallen to $193.32 - a fall of 2.1 percent, or an average decline of 0.2 percent per annum.

Pharmac perceives the level of pharmaceutical subsidisation as a worldwide problem ballooning beyond the ability of governments to contain it in the long term. Pharmac appears further to believe that it has been able to restrain growth to a more manageable level in New Zealand. The RMI believe Pharmac has restricted the pharmaceutical industry to the point that the government's provision for pharmaceuticals has fallen in general. Each of these analyses has its limits. Pharmac is extrapolating from current growth rates into the future but if, as they claim, conflict is likely to increase between taxpayers and patients pressure will increase and, as more restrictions are placed on the pharmaceutical industry, the growth rate will fall. The choice of years from the RMI is curious as Pharmac came into existence in 1993. The level of change in real government expenditure over this period may be significantly different than the figure quoted above.

It was revealed in Parliament on 10 June 1997 that the accumulated savings made by Pharmac since it's establishment were expected to exceed $100 million by June 1997.[37] This represents a slowing of the rate of growth of pharmaceutical expenditure to around 6 per cent per annum. This rate is far larger than the 1.3 per cent increase attributable to demographic changes. The additional 4.7 percent may represent either increased room for savings on the part of Pharmac or a premium paid for an increased quality of drugs.

Unfortunately not all has gone to plan for Pharmac. It has been estimated that Pharmac could exceed its budget for 1997 by up to 78 million dollars. The responses to the overspending

---

[36] Originally from *The Pharmaceutical Industry In New Zealand - RMI Annual Review 1996-97.* Source: www.nzhealth.co.nz/rmi/press/factmar97.html.

[37] Parliamentary Question 8, Tuesday 10 June 1997

of Pharmac's notional budget have been relatively predictable. Pharmac's response was to blame GPs, claiming that they were being captured by drug companies' sustained and slick marketing approaches. Pharmac appear to suggest in *The National Business Review* of September 19, 1997 that they may use pharmacists to monitor the prescribing habits of doctors.

The RMI, through its Chief Executive Kim Miles, stated that it considered it was unreasonable to blame anyone but Pharmac. The following is a portion of a September 1997 press release from the RMI.[38]

> Pharmac needs to assure the public that there is a solid basis for its stated concern about pharmaceutical cost blowouts when it predicts expenditure could exceed budget by $78 million this year than thereby threaten treatment for many thousands of patients
>
> Pharmac's concession that year after year its budget in insufficient to meet the nation's forecast medicine bill is a telling admission, and is especially bad news for patients...
>
> ...Why isn't the budget being set to meet the forecast? Few people could believe that these massive increases in medicine use come out of the blue. Either there needs to be a radical change to the budget-setting process , or Pharmac needs to explain why there is such a big gap between budgeted and actual pharmaceutical expenditure.

If, as the RMI claim, Pharmac knew of the problems it is strange that budgets were not correctly assigned. Pharmac's explanation for the overspend was, primarily, that doctors were prescribing more expensive drugs ahead of cheaper alternatives. This was said to hold most strongly for in the area of heart, gastro-intestinal and hypertension treatments. Presumably the more expensive drugs Pharmac refers to were in different subgroups than the cheaper alternative drugs. Were this not the case Pharmac's budget would be the same regardless of which drug was selected for treatment. Pharmac faces a serious problem here as doctors whose patients face two options with the same price to the patient will naturally tend to select the better option for the patient rather than the taxpayer. David Moore, the general manager of Pharmac, intimated that unless the budget could be controlled "it could get to the stage where we might have to get quite Draconian".[39]

The relationship between Pharmac and the drug companies can be described as at least tumultuous in nature. Over the course of Pharmac's history several lawsuits have been

---

[38] See the RMI website at http://www.nzhealth.co.nz/rmi/press/rel2sep.html.

[39] *Sunday Star Times*, September 14 1997 p.1-2

exchanged between the parties. The health select committee was informed by David Moore that the cost of this litigation could reach $6.3 million by the end of next year if all current cases proceeded to court.[40]

A large amount has written on the efficacy of reference pricing, much of it highly contradictory. Now that the claims made elsewhere have been outlined, the model developed here is used to attempt to discover which claims are more accurate.

III. MODEL PREDICTIONS

Before identifying the outcomes in the cases addressed in earlier chapters it is worthwhile to look at the properties of the profit function under reference pricing. This analysis allows for more precise interpretation of the cases in question. For simplicity reasons the chain of distribution for pharmaceuticals is ignored with the consequence that, in an unregulated model, the consumer price charged by the firm equals the price the patient actually faces.

(1) Continuous profit function

The variant of reference pricing addressed here is of a more general setting than the reference pricing system used in New Zealand. The patient price of the pharmaceutical is assumed to be a minimum charge k in addition to any existing price differential.[41] This allows the properties of the profit function to be derived not only for New Zealand's system but also for alternatives that may be used when comparing the current system of reference pricing to systems that impose positive charges on patients.

Where reference pricing exists the profit function of firm j remains continuous. Suppose that the pricing decisions for all other drugs in a given subgroup have been made. The reference price amongst these drugs is referred to as a *de facto* reference price, r' and the prevailing

---

[40] NZPA-Political 29/05/1997

[41] For simplicity reasons it is assumed throughout this thesis that the chain of distribution from the producer to the patient is costless. Manufacturers receive the pertinent subsidy plus whatever sum the patient contributes towards their treatment. It is acknowledged that this is does not actually occur in New Zealand - the true scheme is analysed in Appendix 6.4.

reference price is denoted by the letter r. This prevailing reference price is set only after the pricing decision of the drug in question.

Suppose that a firm decides to set price above the *de facto* reference price so that the *de facto* reference price coincides with the actual reference price. The prices observed by patients are $p_i^c = k + p_i - r = k + p_i - r'$. When varying the price of the subject drug the consumer prices of other drugs are not affected because it is not the reference priced drug. As the price of the subject drug approaches the *de facto* reference price (from above) the prices observed by patients are:

subject drug: $p_i \to k$

de facto reference price drug: k

other drugs: $k + p_i - r'$

Suppose that a firm decides to set price below the *de facto* reference price so that the subject drug becomes the reference priced drug. The consumer prices observed for all other drugs will be $p_i^c = p_i - p_j$. As the price of the subject drug increases towards the value of the *de facto* reference price the consumer prices for all other drugs fall. These consumer prices are:

subject drug: k

de facto reference price drug: $k + r' - p_j \to k$

other drugs: $k + p_i - p_j \to k + p_i - r'$

And so from above and below the consumer prices observed are identical where the price of drug j equals the *de facto* reference price. Since every patient has the same information regardless of how p_j approaches r' the choice made by patients is the same in either case and the quantities are identical. At r' the limits of the profit function from above and below are equal and so the profit function is continuous.

(2) Discontinuous first derivative of the profit function

While the profit function is continuous under reference pricing, its first derivative is not. At r' the effect of a price change differs. Where the price of the drug in question is below the *de facto* reference price (r') an increase in price is analogous to a decrease in the consumer price of all other drugs. For prices above r' an increase in the price of a drug is perceived by consumers

as an equally sized increase in price. Since own price sensitivity should outweigh the cross price sensitivity the profit function will have a kink at r'. This raises the possibility of three distinct types of outcome in the model: pricing at a premium, matching price and pricing to become the reference priced drug. Sample profit functions associated with each type of behaviour are given below.

Where firms have an incentive to price above the *de facto* reference price there is a single local maximum of the profit function. An example of this lies in the diagram below where the profit function has a unique maximum to the right of the *de facto* reference price (see inset).[42] This form of behaviour is expected where a competitor sets price at a particularly low level. In this case the cost of matching the reference price exceeds that of attracting a part charge for patients.[43]

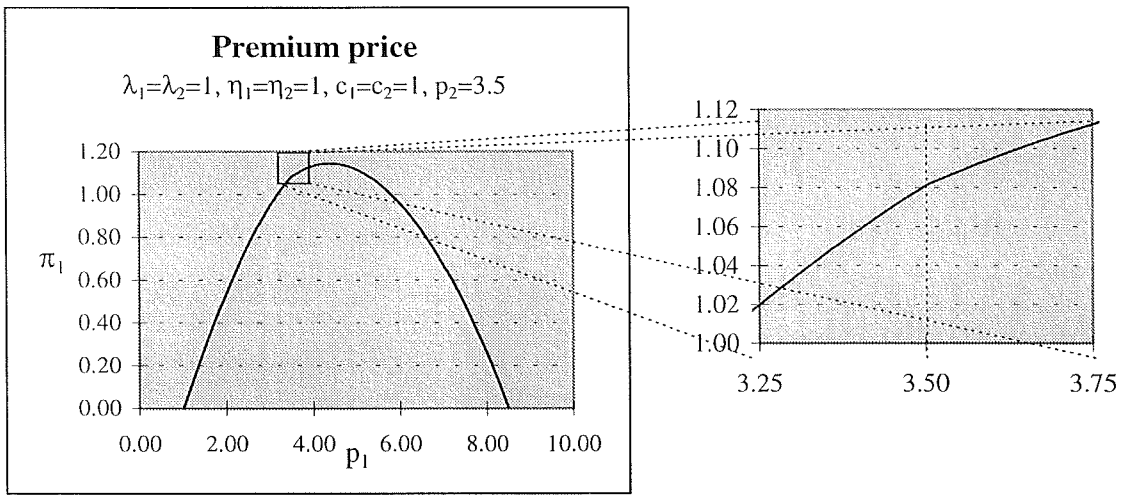


Figure 6.1: Premium pricing.[44]

Firms will choose for their drugs to be reference priced where a local maximum both exists and promotes a price below that of the *de facto* reference price. The below diagram displays an example of the profit function where the price corresponding to the unique local maximum is to

---

[42] All diagrams in this section implicitly set the universal drug charge (k) to zero. This is not significant however since the results here rely on the differing effects of price changes above and below the de facto reference price. This behaviour does not depend on the universal drug charge.

[43] Above any charge k, that is levied regardless of drug.

[44] Profits in millions of dollars.

the left of the competitor's price. The inset displays an expanded view of the profit function displaying both the local maximum and the competitor's price.

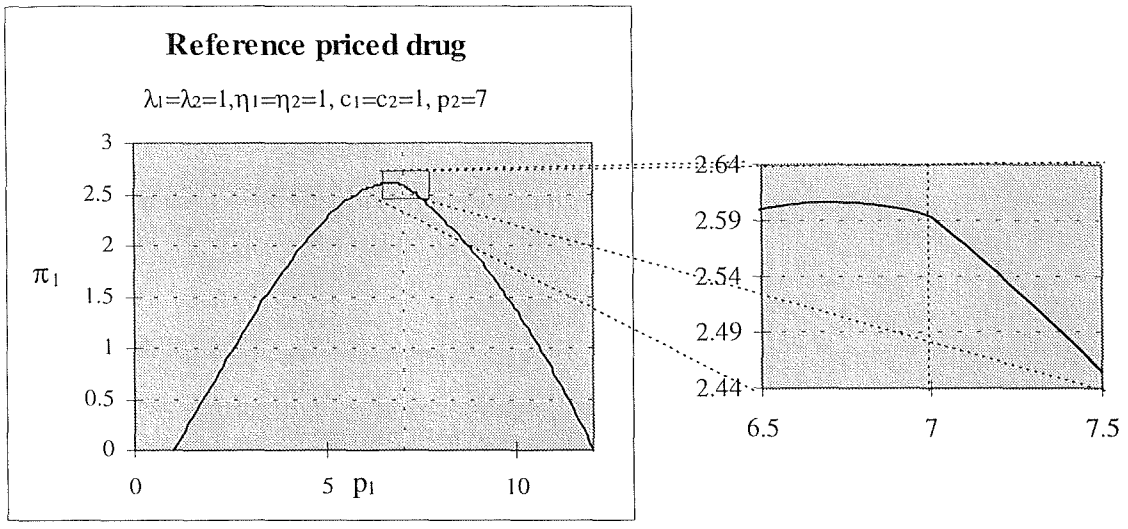


Figure 6.2: Undercutting.[45]

The final form of behaviour under reference pricing is to match prices. Firms will match prices where there is no local maximum in the profit function[46] but rather a pronounced kink at the *de facto* reference price. The general appearance of the profit function when firms choose to match the *de facto* reference price is given below.

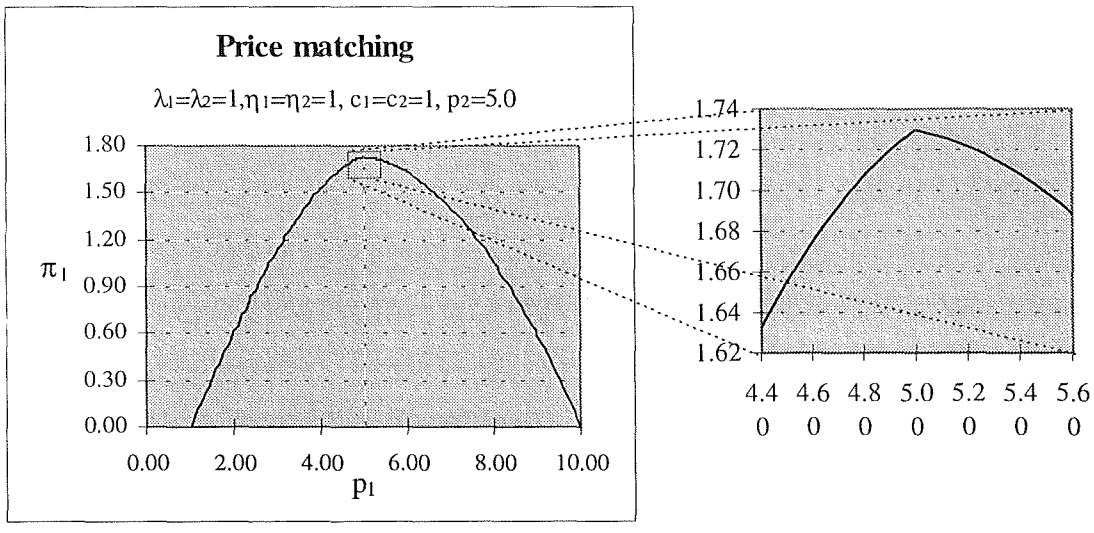


Figure 6.3: Matching reference price.[47]

---

[45] Profits in millions of dollars.

[46] In the sense of a point with $\frac{d\pi}{dp} = 0, \lim_{(p \to r')^+} \frac{d^2\pi}{dp^2} = \lim_{(p \to r')^-} \frac{d^2\pi}{dp^2} < 0$.

[47] Profits in millions of dollars.

By searching for a local maximum any existing premium or reference price outcomes can be found. Where no local maximum exists the estimate of the profit maximising price will automatically converge to the reference price. Using *Microsoft Excel*'s goal seek function the value of a firm's reaction function at a point may be found. By varying the price of the competing firm the entire reaction function can be derived.

(3) Model results

The cases explored in previous chapters were reviewed under reference pricing and the outcomes obtained compared with those seen under an unregulated duopoly framework and with those under marginal cost provision of pharmaceuticals. Reference pricing is examined under two differing schemes: RP (zero charge) examines the system where a reference priced drug attracts a zero patient price while RP (MC charge) assigns a charge of marginal cost to each drug in addition to any positive price differential. The alternative system considered in the following chapter is assigned the abbreviation JZ[48] and also has two variants of interest corresponding to those pertinent for reference pricing: JZ (zero charge) and JZ (MC charge). These schemes, as with the reference pricing variants, assign zero and marginal cost patient charges respectively. These four variants allow the schemes to be compared in a sensible fashion. Each type of charge allows comparison of the subsidies required for each scheme while keeping patient prices as close as possible. Since no framework has yet been defined for the JZ scheme little can be said regarding its cost.

One important consideration enters when we refer to efficiency. Efficiency measures the difference between the total willingness to pay of consumers who choose to undertake treatment and the aggregate costs borne by all parties. As transfer payments subsidies paid by the government to drug companies do not affect efficiency in a world where raising taxes does not change the choices of individuals and firms. This situation corresponds to the first 'total surplus' column in the summary table of each case. The second 'total surplus' column refers to the case where the raising of $1 in taxes effectively costs $1.10 to taxpayers because of the distortions taxes cause in the economy. This figure has been used due to an unfruitful search for a generally

[48] In deference to Johnston and Zeckhauser who proposed the scheme that will be used in comparison to reference pricing in a static, perfect information case.

accepted level of the marginal deadweight loss from taxation. Every report appears to state how not to calculate the figure but very few actually attempt the estimation.[49]

(a) Identically distributed drugs

Appendix 6.2 considers the type of equilibria we expect in the situation where we have two drugs with qualities that are distributed identically and independently. The results suggest that we expect that there will be a range of shared prices over which equilibria occur.[50] This complicates the analysis of the case of identically distributed drugs somewhat as there is no unique reference pricing outcome that may be compared with the outcomes of other systems. The reaction curves for each firm (where reference priced drugs attract a zero patient price) the scenario where $\lambda_i = \eta_i = c_i = 1$ are given below.

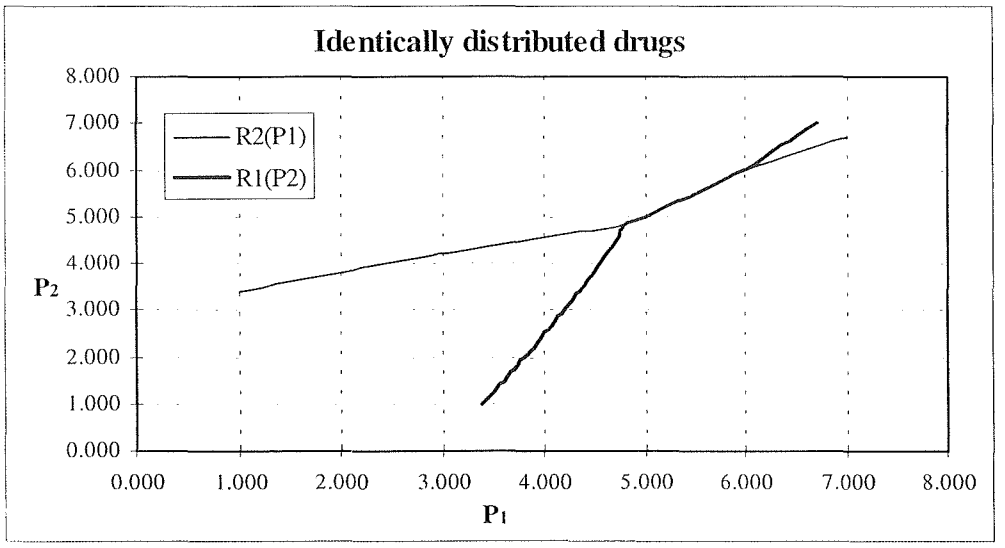


Figure 6.4: Identically distributed drugs

The range of prices over which the multiplicity of equilibria occur are from $p_1 = p_2 = 4.8080$ to $p_1 = p_2 = 6.0000$. The following tables attempt to summarise this scenario and compare it to that observed under the unregulated model of the previous chapter, in addition to

[49] The case of a distortionary tax was included only to show how sensitive the result that reference pricing was superior to the unregulated position actually was. Beyond this very little can be taken from this figure.

[50] Unless initial prices are low and firms are reluctant to signal high prices the high price outcome may be more realistic in the absence of restrictions on how firms may set their price.

marginal cost provision of pharmaceuticals. Two rows have been allocated for reference pricing, giving the extreme points of the range of equilibria.

Where marginal cost is charged for each drug under reference pricing a range of equilibria also exist. Shared prices between 4.32 and 6.00 promote the situation where both firms charge marginal cost to patients and receive the appropriate subsidy ($p_i - c_i$) from the government. This case is also analysed using two rows of the following tables outlining the results under the extreme points of this range.

	p_1	p_2	p_1^c	p_2^c	μ_1 (m)	μ_2 (m)	μ_N	π_1	π_2
Unregulated duopoly	2.95	2.95	2.95	2.95	0.28	0.28	0.44	0.55	0.55
RP (zero charge - high)	6.00	6.00	0.00	0.00	0.43	0.43	0.14	2.16	2.16
RP (zero charge - low)	4.81	4.81	0.00	0.00	0.43	0.43	0.14	1.64	1.64
JZ (zero charge)	-	-	0.00	0.00	0.43	0.43	0.14	-	-
RP (MC charge - high)	6.00	6.00	1.00	1.00	0.40	0.40	0.20	2.00	2.00
RP (MC charge - low)	4.32	4.32	1.00	1.00	0.40	0.40	0.20	1.32	1.32
JZ (MC charge)	-	-	1.00	1.00	0.40	0.40	0.20	-	-

Table 6.1: Identically distributed drugs (1 of 2).

The above table gives predictable results. Producer prices are highest under reference pricing because of the subsidies on offer. Predictably consumption is highest under the zero price schemes, followed by the schemes providing drugs at the shared marginal cost and the unregulated case respectively. Profits are highest in the reference pricing cases since both producer prices and quantities are at their highest levels here.

The table below completes the summary of the case of identically distributed drugs. Consumer surplus is understandably highest under the zero price outcomes, followed by the MC and the unregulated duopoly scenarios, reflecting the relationship between consumer prices and consumer surplus. The subsidy cost shows (trivially) that the cost of a subsidised scheme is greater than where no subsidies exist. Because at this time no framework has been analysed with respect to the JZ scheme nothing more can be said about this at this time. As would be expected reference pricing is cheaper to the subsidising agency when a part charge (in this case marginal cost) is levied on patients.

	p_1	p_2	p_1^c	p_2^c	*consumer surplus*	*subsidy cost*	*total surplus*	*total surplus (10% DWL)*
Unregulated duopoly	2.95	2.95	2.95	2.95	\$0.6534 m	\$0.0000 m	\$1.7437 m	\$1.7437 m
RP (zero charge - high)	6.00	6.00	0.00	0.00	\$2.8383 m	\$5.1880 m	\$1.9737 m	\$1.4549 m
RP (zero charge - low)	4.81	4.81	0.00	0.00	\$2.8383 m	\$3.2926 m	\$1.9737 m	\$1.6444 m
JZ (zero charge)	-	-	0.00	0.00	\$2.8383 m	-	\$1.9737 m	-
RP (MC charge - high)	6.00	6.00	1.00	1.00	\$2.0047 m	\$3.9905 m	\$2.0047 m	\$1.6057 m
RP (MC charge - low)	4.32	4.32	1.00	1.00	\$2.0047 m	\$2.6499 m	\$2.0047 m	\$1.7397 m
JZ (MC charge)	-	-	1.00	1.00	\$2.0047 m	-	\$2.0047 m	-

Table 6.2: Identically distributed drugs (2 of 2).

As far as efficiency is concerned where taxes are non-distortionary the reference pricing outcomes are superior to those of an unregulated position in terms of efficiency. Reference pricing however involves a large transfer from the government to the drug companies which may make it unpalatable as a choice of regulatory regime. The major component behind the relative efficiency of reference pricing here is the low consumer cost it promotes. The highest efficiency predictably arises where price equals marginal cost.

Where the distortionary effects of taxation are taken into account the results obtained change markedly. Even at a relatively small distortionary cost to taxation (10% DWL) the unregulated position becomes more efficient as the increase in consumer surplus resulting from reference pricing becomes too costly in terms of efficiency.

(b) Large asymmetry in efficacy

As in previous chapters this scenario assumes two drugs exist in a subgroup with side effects that are independently and identically distributed. There is however a large difference in efficacy between the drugs with drug 1 having twice the efficacy of its competitor ($\eta_i = c_i = 1, \lambda_1 = 1, \lambda_2 = 0.5$). The following diagram displays the reaction curves for each drug under the RP (zero charge) case.

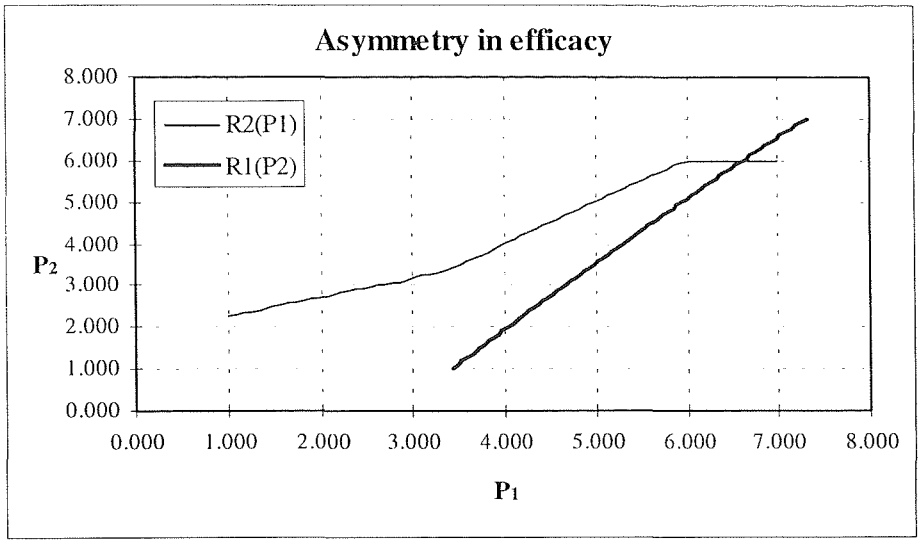


Figure 6.5: Asymmetry in efficacy

The unique Nash equilibrium under reference pricing predictably involves the higher quality drug charging a higher price and obtaining a higher proportion of the market.[51] The reference pricing outcome with marginal cost charged to patients also has a unique Nash equilibrium in this case which is quite close to that of the zero charge case.

	p_1	p_2	p_1^c	p_2^c	μ_1 (m)	μ_2 (m)	μ_N	π_1	π_2
Unregulated duopoly	3.15	1.75	3.15	1.75	0.30	0.10	0.59	0.65	0.08
RP (zero charge)	6.63	6.00	0.63	0.00	0.53	0.22	0.25	2.98	1.09
JZ (zero charge)	-	-	0.00	0.00	0.59	0.19	0.22	-	-
RP (MC charge)	6.21	6.00	1.21	1.00	0.53	0.14	0.33	2.65	0.71
JZ (MC charge)	-	-	1.00	1.00	0.53	0.14	0.33	-	-

Table 6.3: Asymmetry in efficacy (1 of 2).

The above table outlines the prices and quantities associated with reference pricing in addition to that of the unregulated duopoly and JZ cases. This table provides the same general conclusions as did the corresponding table in the case of identically distributed drugs. Reference pricing is associated with the highest level of producer prices followed by the unregulated distribution. Although the patient price for drug 1 under reference pricing is positive in both cases the level of consumer prices is still lower under the reference pricing framework than the unregulated duopoly case. The JZ (zero charge) case does however promote lower prices than its

[51] See Appendix 6.3 for the case where equilibria switch from a range of shared prices to a single point..

reference pricing alternative. With high producer prices and a large quantity corresponding to low consumer prices the reference pricing outcomes again involves higher profits for both firms than the unregulated case. Reference pricing is again failing in its bid to keep subsidy payments low as the profits accruing to the producers of the inferior drug are ten times that expected in an unregulated case.

Table 6.4 further analyses this case and compares reference pricing with its alternatives. The conclusion of the previous case holds again as reference pricing is again more efficient than an unregulated duopoly where taxes are non-distortionary but not so when such distortions are taken into account.

	p_1	p_2	p_1^c	p_2^c	*consumer surplus*	*subsidy cost*	*total surplus*	*total surplus (10% DWL)*
Unregulated duopoly	3.15	1.75	3.15	1.75	\$0.3420 m	\$0.0000 m	\$1.0681 m	\$1.0681 m
RP (zero charge)	6.63	6.00	0.63	0.00	\$1.7233 m	\$4.4818 m	\$1.3093 m	\$0.8612 m
JZ (zero charge)	6.00	6.00	0.00	0.00	\$2.0742 m	-	\$2.0742 m	-
RP (MC charge)	6.21	6.00	1.21	1.00	\$1.2397 m	\$3.2646 m	\$1.2397 m	\$0.9132 m
JZ (MC charge)	-	-	1.00	1.00	\$1.3485 m	-	\$1.3485 m	-

Table 6.4: Asymmetry in efficacy (2 of 2).

(c) Large asymmetry in risk

This scenario addresses the case of two firms where both share a common efficacy ($\lambda_i = 1$) but the risk of drug 1 is far lower than its alternative ($\eta_1 = 5, \eta_2 = 1$). Marginal costs are again constant and equal to 1. With a large asymmetry between the firms it is expected that there is only one Nash equilibrium in prices. This is confirmed by the diagram below which displays the reaction curves of each firm under RP (zero charge) and shows a single intersection at $p_1 = 5.59, p_2 = 4.10$.

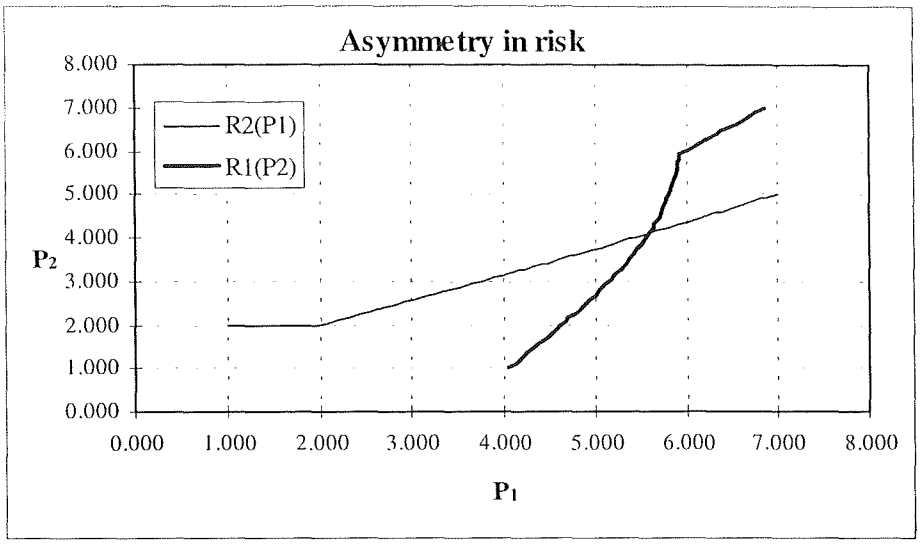


Figure 6.6: Asymmetry in risk.

The table associated with this case is given below.

	p_1	p_2	p_1^c	p_2^c	μ_1 (m)	μ_2 (m)	μ_N	π_1	π_2
Unregulated duopoly	3.42	2.71	3.42	2.71	0.61	0.26	0.13	1.49	0.44
RP (zero charge)	5.59	4.10	1.48	0.00	0.61	0.38	0.01	2.80	1.18
JZ (zero charge)	-	-	0.00	0.00	0.83	0.17	0.00	-	-
RP (MC charge)	5.05	3.79	2.26	1.00	0.62	0.35	0.03	2.53	0.97
JZ (MC charge)	-	-	1.00	1.00	0.83	0.17	0.01	-	-

Table 6.5: Asymmetry in risk (1 of 2).

The same conclusions as found previously apply here almost universally. The ordering of producer prices is identical to previous cases, as are quantities and prices. The large difference in risk promotes a large price differential between the two drugs in excess of the $1.00 that would be charged for drug 1 under JZ (MC charge). Here the average level of patient charges under reference pricing is lower than under marginal cost pricing but the 61% of patients using drug 1 face more expensive treatment.

	p_1	p_2	p_1^c	p_2^c	*consumer surplus*	*subsidy cost*	*total surplus*	*total surplus (10% DWL)*
Unregulated duopoly	3.42	2.71	3.42	2.71	$1.0114 m	$0.0000 m	$2.9362 m	$2.9362 m
RP (zero charge)	5.59	4.10	1.48	0.00	$3.1056 m	$4.0597 m	$3.0222 m	$2.6162 m
JZ (zero charge)	-	-	0.00	0.00	$4.1687 m	-	$4.1687 m	-
RP (MC charge)	5.05	3.79	2.26	1.00	$2.2610 m	$2.7097 m	$2.2610 m	$1.9900 m
JZ (MC charge)	-	-	1.00	1.00	$3.1735 m	-	$3.1735 m	-

Table 6.6: Asymmetry in risk (2 of 2).

The above table preserves the efficiency orderings found earlier. Reference pricing is again more efficient than an unregulated duopoly where taxes can be raised in a non-distortionary fashion but not when subsidies place an additional 10% burden on society. Marginal cost provision is again superior in the initial comparison but nothing more may be said in the distortionary case since the financing costs of this option are unknown.

(d) Balanced asymmetry

The final case explored is that of a situation where the superior safety of drug 1 approximately balances the superior efficacy of drug 2. Here $\lambda_1 = 0.85, \eta_1 = 1.10$, $\lambda_2 = 0.90, \eta_2 = 1.00$ and $c_i = 1$. Appendix 6.2 suggests that these two drugs, being generally balanced, will have a range of prices where it pays each to match the price of the other. The reaction curves below confirm that this is indeed the case and that at all shared prices between 4.5127 and 6.0000 there is a Nash equilibrium.

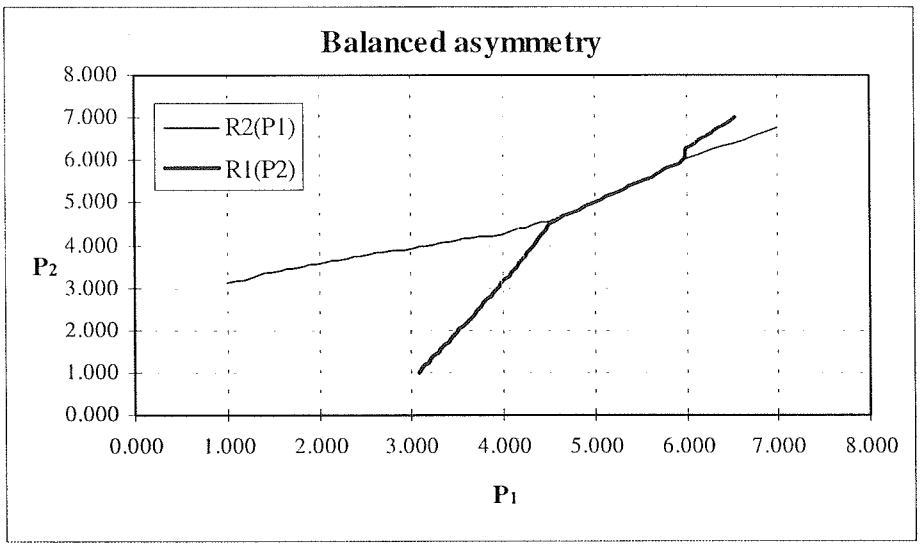


Figure 6.7: Balanced asymmetry.

The problems of analysis where there are a range of Nash equilibria arise here again. Fortunately the results found once more do not depend on which Nash equilibrium is chosen. Reference pricing under a marginal cost charge also promotes a range of shared price Nash equilibria. For both cases the high and low extrema of the ranges are examined in the tables below.

	p_1	p_2	p_1^c	p_2^c	μ_1 (m)	μ_2 (m)	μ_N	π_1	π_2
Unregulated duopoly	2.61	2.73	2.61	2.73	0.25	0.26	0.49	0.41	0.44
RP (zero charge - high)	6.00	6.00	0.00	0.00	0.41	0.43	0.16	2.07	2.13
RP (zero charge - low)	4.51	4.51	0.00	0.00	0.41	0.43	0.16	1.46	1.50
JZ (zero charge)	-	-	0.00	0.00	0.41	0.43	0.16	-	-
RP (MC charge - high)	6.00	6.00	1.00	1.00	0.37	0.39	0.24	1.86	1.93
RP (MC charge - low)	3.91	3.91	1.00	1.00	0.37	0.39	0.24	1.08	1.12
MC provision	-	-	1.00	1.00	0.37	0.39	0.24	-	-

Table 6.7: Balanced asymmetry (1 of 2).

Once more the general conclusions of the other cases hold here. Producer prices are highest and consumer prices lowest under reference pricing. Profits for both drugs are higher under the reference pricing framework than the unregulated case. Where the firms charge at marginal cost the slightly superior drug 2 obtains a greater share of the market and consumption is lower than under reference pricing.

	p_1	p_2	p_1^c	p_2^c	*consumer surplus*	*subsidy cost*	*total surplus*	*total surplus (10% DWL)*
Unregulated duopoly	2.61	2.73	2.61	2.73	\$0.4883 m	\$0.0000 m	\$1.3408 m	\$1.3408 m
RP (zero charge - high)	6.00	6.00	0.00	0.00	\$2.3714 m	\$5.0423 m	\$1.5310 m	\$1.0267 m
RP (zero charge - low)	4.51	4.51	0.00	0.00	\$2.3714 m	\$2.9520 m	\$1.5310 m	\$1.2358 m
JZ (zero charge)	-	-	0.00	0.00	\$2.3714 m	-	\$1.5310 m	-
RP (MC charge - high)	6.00	6.00	1.00	1.00	\$1.5697 m	\$3.7854 m	\$1.5697 m	\$1.1912 m
RP (MC charge - low)	3.91	3.91	1.00	1.00	\$1.5697 m	\$2.2005 m	\$1.5697 m	\$1.3497 m
JZ (MC charge)	-	-	1.00	1.00	\$1.5697 m	-	\$1.5697 m	-

Table 6.8: Balanced asymmetry (2 of 2).

The conclusions of the other cases once more hold almost perfectly here with reference pricing superior on efficiency grounds where taxes are assumed to cause no distortions in the economy. Where distortions exist this result is reversed where the reference pricing scheme assigns zero patient cost to reference priced drugs. Where reference pricing assigns a marginal cost levy to drugs it is possible that the scheme may be more efficient than the unregulated case at relatively low levels of distortion.

IV. EVALUATION OF RESULTS

The results of the scenarios examined are clear and consistent between the cases. The reference pricing scheme is far superior to an unregulated duopoly as far as consumers are concerned. The economy is however worse off than in an unregulated market where taxes are distortionary. The cases addressed considered where drugs were distributed identically, had a roughly balanced quality distributions, and where large differences existed between the distributions individual specific qualities were drawn from. Small differences between distributions were assessed in the balanced asymmetry case, as if there was a disparity of the effects of small differences in risk and efficacy it would have appeared in the results of this case. The residual difference between the drugs after offsetting the advantages of each (drug 2 is marginally superior) did not have a major impact on the results. It is therefore unlikely that small differences in either efficacy or risk will change the outcomes significantly from that of the identically distributed drugs case.

The most interesting result from this analysis is the level of prices observed where reference pricing is applied to the market. As a subsidisation scheme it is not surprising that the prices of each good increase as a result of reference pricing but the magnitude of these increases is extreme. Prices are ineffectively constrained by reference pricing where firms may freely enter into a subgroup adjust prices to reach the Nash Equilibrium. In many cases equilibrium prices may occur above the level that, if the cost of pharmaceuticals were to be levied directly on to consumers, the last consumer would have long left the market.[52] This is not the behaviour expected of a scheme that is supposed to restrict prices and force firms to compete vigorously on price.

That Pharmac has managed to keep prices at the level it has appears to be more to do with the restrictions it places on entry into subgroups than reference pricing itself. More will be said of these restrictions in Chapter 10 where a more comprehensive analysis of the pharmaceutical

---

[52] Recall that patients will undertake a course of treatment only if $\varphi < \%$. The quality (φ) of any drug has a value of at most λ so that the final consumer will decline treatment by this drug when price exceeds λL. Since λ is constrained to be at most 1 and L is assumed to equal 5 throughout this thesis the maximum value λL can take is 5. For any value of the producer price above 5 it is certain that no one would ever choose to undertake treatment were the producer price directly levied.

market takes place. The question then remains of Pharmac, why use a system that at least in an unrestricted form fails to contain both producer prices and quantity when other systems may be available to provide pharmaceuticals at a more reasonable price? One potential scheme, identified by Woodfield, Fountain and Borren, is evaluated in the following chapter to ascertain whether it provides a better method for the subsidisation of pharmaceuticals.

Although efficiency is used to evaluate alternative schemes here it must be noted that efficiency is unlikely to ever be the government's primary aim when addressing the area of health. While efficiency is something that is aimed for the primary aim is normally the provision of health services at a cost effective level. Those who would otherwise be unable to undertake treatment attract special attention from the government. The use of reference pricing fails when dealing with these patients since it does not necessarily provide pharmaceuticals to patients at a price at or below marginal cost.[53] Additionally, since reference pricing (in the absence of marginal cost differences) may result in less efficacious and/or more risky drugs being fully subsidised, reference pricing may encourage the use of lesser treatment alternatives.

Whether a government considers that pharmaceuticals should be provided below marginal cost is an ethical question rather than an economic one but the economics involved are nonetheless significant. The increased cost of the scheme must be compared with the welfare gains to society obtained by reducing the uncertainty citizens face regarding illness. With a wide variety of treatments available for a myriad of illnesses it is unlikely that all pharmaceuticals will ever be free to consumers since this would imply a massive cost to the government in the form of subsidy payments. Where prices are positive the simplest way to keep expenditure at an acceptable level is to use prices to accurately convey the relative costs of pharmaceuticals and allow patients to observe the true cost of pharmaceuticals.

The pros and cons of pricing pharmaceuticals at marginal cost are covered in the following chapter which outlines a possible alternative to the reference pricing scheme used in New Zealand.

---

[53] See Table 6.5 where for the zero fixed charge reference pricing scheme $p_1^c = 1.48 > 1 = c_1$.

V. CAVEATS

The removal of the search component of the model weakens the results obtained here but is unlikely to reverse the evidence presented. The search model implicitly places the firms in any subgroup on a more combative footing and opens up new avenues for competition between them. It has not been possible to explore these avenues because of the non-existence problem encountered. The search model would have expanded the analysis of reference pricing in the following ways:

(i) The search model is based on imperfect information since patients are unsure of the precise effect any particular pharmaceutical will have on them. The repercussions of such uncertainty are important in the decisions they make. With costly information it is not necessarily the case that patients make the final choice of treatment with all relevant information. As doctors are the agents most likely to provide information over both which drugs are worthwhile to test and the likely quality of treatments, drug companies may compete for custom by competing for the attention of doctors.

(ii) When dealing with generic drugs the estimation of doctors over the quality of drugs is vital in the probability of a generic drug successfully obtaining a significant share of the market. Lobby groups representing the companies responsible for researching new medicines may be able to convince doctors of differences between drugs and their generic copies where no such differences exist. If this occurs it is likely that generic firms will be unable to make significant penetration into the marketplace.

(iii) With a more competitive environment it may be possible that reference pricing would have fared better than at present since the drug companies may have competed more vigorously. Alternatively prices may have been even higher under reference pricing within a search framework if the drug companies choose to compete more strenuously on the basis of doctor's loyalties than on price. Very little can be said on this topic and it seems likely that the search model would not have overturned the large prices observed.

The numerical analysis in this chapter does not necessarily reflect the method Pharmac uses when determining pharmaceutical subsidies because it implicitly assumes that firms are placed on an even footing by being allowed to compete in the marketplace. In reality there is no guarantee that any firm will be given entry to a therapeutic subgroup and Pharmac does appear to

attempt to utilise its strategic advantage to force firms to agree to concessions before it will permit entry. This may reduce the cost of pharmaceuticals but may lead to non-subsidisation of pharmaceuticals. Pharmac is not aided in this strategic behaviour by using reference pricing however since reference pricing does not appear to promote low producer prices which in turn increases the cost of accepting a bid for listing on the Pharmaceutical Schedule. A regulatory system promoting lower producer prices may allow Pharmac to achieve subsidisation at lower prices rather than face a situation where drugs representing an advances in treatment are left unsubsidised.

CHAPTER 7

A PROPOSED ALTERNATIVE

The reference pricing system used in New Zealand and overseas has come under attack because it is suggested that it does not fully utilise the government's strategic advantage in negotiations. The 1997 report by Woodfield, Fountain and Borren suggested that alternative schemes for subsidising pharmaceuticals could allow the government to exploit its strategic position by forcing the firms to compete for subsidisation. In the purest forms of reference pricing this competition is not evident.

The system used by the Australian Government in the 1980's demands examination in order to ascertain whether it promotes a superior outcome to that observed under reference pricing. When comparing the two systems both efficiency and the price of subsidisation should be considered. Additionally, consideration may be given to the level of patient care provided in equilibrium and the informational requirements of each scheme. The Australian scheme imposes much greater informational demands on the agency negotiating subsidisation of pharmaceuticals. While it may be the case that the 1980's Australian scheme is superior to that of reference pricing in a world of perfect information, it is not necessarily the case when the pharmaceutical agency is faced with realistic constraints on their information. This chapter compares the schemes in a world of perfect information while Chapter 10 explores the comparison under imperfect information.

I. WOODFIELD, FOUNTAIN AND BORREN'S EXAMINATION OF 1980'S SCHEME

In Woodfield *et al* analysis of the Australian scheme was based on standard textbook model of duopoly examined by Johnston and Zeckhauser (1991) which was expanded to encompass cases beyond that of identically characterised firms. Each firm was initially given a linear demand function and an identical marginal cost under constant returns to scale. The products were differentiated, allowing firms to charge above the level of their competitor and

retain a positive share of the market. The benchmark against which the scheme was compared was the Nash equilibrium in the Bertrand pricing game.

The numerical example given by Johnston and Zeckhauser issued both firms with a demand function

$X_i = 10 - P_i + 0.25P_j$ where the X_i's are in millions of patients

and a cost function

$C(X_i) = 2X_i,$ $i = 1,2.$

Under these assumptions the Nash equilibrium results in each firm charging a price of $6.86 and receiving $23.6 million in profit.

The first option put forward by Johnston and Zeckhauser was to subsidise only one of the firms. The assumption made earlier in this thesis is made here also, that the distributor of drugs bears no costs in transferring products to consumers. Under this assumption the price of medication to the patient equals the marginal cost of the producer. The minimum subsidy required for either firm to join the scheme gives the firm only the profits it would otherwise forego by charging at marginal cost. The response of the unsubsidised firm is not ignored as the lowering of the price of the unsubsidised drug shifts the demand curve the subsidised drug faces and so affects the per-unit subsidy required. In the above example the price of the unsubsidised drug falls to $6.25, requiring the producer to receive a unit price of $4.47 to compensate for the loss of $23.6 million in profits. A producer price of $4.47 implies a unit subsidy of $2.47 since $2 per unit is already received by the producer in the form of consumer payments. The unsubsidised firm faces profits of only $18.1 million after the introduction of the subsidy.

In this initial option the subsidised firm is incited to move off its reaction function by the offer of subsidisation, leading to a decrease in its price while holding its profits constant. The unsubsidised firm, facing a lower price from its subsidised competitor, responds with a lower price and faces decreased quantity and profits. While the subsidised firm observes no difference in its profits as a result of subsidisation the unsubsidised firm is greatly affected. If both firms are to be subsidised there are two options facing the government: either subsidise them both to compensate for the $23.6 million lost when pricing at marginal cost, or alternatively, use the fact

that being unsubsidised represents a large decrease in profits if a competitor is subsidised to its own budgetary advantage.

If the government was to subsidise both firms for the loss of $23.6 million dollars it would lead to consumer prices of $2, producer prices of $4.8 and a unit subsidy of $2.8. The total cost to the government of such a scheme is $47.2 million dollars.[1] This subsidisation scheme was earmarked option two by Johnston and Zeckhauser.

Johnston and Zeckhauser's option three used the government's strategic advantage to better effect. One firm was approached with the offer of subsidisation from the original Nash equilibrium level. If the first firm accepted the offer of subsidisation the second firm was approached but only after sufficient time had elapsed for the full effects of subsidisation to become evident. When approached the second firm needs not be compensated by the full amount of its benchmark profits since it no longer makes profits of the same magnitude. In the numerical example the second firm needs to be compensated by $18.1 million dollars, not the full $23.8 million. The adoption of option three in preference to option two would result in $5.5 million dollars less in subsidy payments to the firms. Firm one receives a per-unit subsidy of $2.8 (as calculated above) while the second firm needs to be compensated by only $2.1 per unit. An interesting point is made here by Woodfield *et al*, the increased profit of $5.5 million accruing to the first firm joining the subsidy may be dissipated by the firms in attempts to be the first invited to join. The potential for such rent seeking need not exist, as evidenced by the fourth option.

Option four uses the strategic position of the government to its best advantage. The agency here offers to subsidise either firm to the level of its equilibrium profits, if it is the only firm to join. If the other firm joins it is offered a subsidy sufficient to give it only the level of profits it would experience if it remain unsubsidised. The fundamental difference between schemes three and four is that under scheme three a piecewise approach is taken where firms are approached in turn with the invitation to join the subsidy scheme. Under option four offers are made simultaneously to both firms which in equilibrium allows neither firm to receive the profits they

[1] As it compensates each firm by $23.6 million.

would have made had no subsidisation been possible. The prisoners' dilemma game defined by this subsidy scheme is given in Table 7.1 below.

		Firm 2	
		join scheme	stay out
Firm 1	join scheme	\$18.1 m, \$18.1 m	\$23.6 m, \$18.1 m
	stay out	\$18.1 m, \$23.6 m	\$23.6 m, \$23.6 m

Figure 7.1: The subsidy game.

Suppose that a firm expects its competitor to join the subsidy scheme. Whether or not the firm joins it expects to make 18.1 million dollars. An epsilon can be added to the profits accruing to the firm in the case where it joins the subsidisation scheme in order to make joining optimal. Suppose now that the firm expects its competitor not to join the scheme. An epsilon can again be added to the payoff of the firm in the case where it joins the scheme in order to make joining the optimum strategy. As joining is now optimal for a firm regardless of the actions of the other firm a dominant strategy equilibrium exists at {join, join}.

Here we get the interesting result that each firm is fundamentally indifferent to whether it joins or not but has strict preferences over whether it's competitor does. In order to remove the indifference highlighted above it is possible to offer profits under subsidy of an epsilon above the unsubsidised equivalent. As with all prisoners' dilemma games the (static) dominant strategy equilibrium involves both players playing against their corporate self interest in playing {join, join}. The profits earned by each firm in equilibrium will be \$18.1 million.

The fourth option is the most cost-effective of the three schemes where both firms are subsidised. In making the decision of whether or not to subsidise two firms it is necessary for the government to take several factors into account. Where both firms are subsidised a favourable aspect of consumer prices is that they reflect the marginal cost of each type of output, giving superior cost information than that which would otherwise have been observed. Where both firms are subsidised patients have the full raft of options available to them at a smaller price than would be observed under an unregulated outcome. The availability of all relevant drugs allows consumers to choose the drug that suits them best. The downside to subsidising a large number

of firms is the obvious increase in cost as well as the cost of increased informational requirements where information is available but costly.

In order to subsidise a firm under any of the four JZ options the cost structure and the characteristics of all relevant drug options must be known for an accurate assessment of the profits and the subsidies necessary under each case. Fixed and marginal costs of a firm must be known under the JZ scheme. Marginal costs must be known since these constitute the post subsidisation price of each drug. If fixed costs are large there is no guarantee that a firm can cover costs when its opposition charges at its marginal cost. If fixed costs are sufficient to prevent profits options three and four involve a choice of whether to remain in the industry and make a loss or to exit and make zero profits. In this case the per-unit subsidy must be large enough to allow the firm to cover costs. This problem is not explicitly referred to in analysis below as fixed costs are set at zero. It is not seriously suggested that firms face no fixed costs but rather that they face fixed costs below the level of profits available to the firm where all other firms are subsidised. Where firms face these moderate fixed costs a zero fixed cost can be assumed without a loss of generality.

Under imperfect information where firms face large enough fixed costs so as to make exit optimal it is likely a very complex signalling mechanism will be required to guarantee subsidisation. The nature of such signalling mechanisms is not addressed in this thesis but is left for future research.[2]

The characteristics of the distributions[3] of all relevant drugs firms are required to find subsidies under the JZ scheme. These characteristics affect the best response functions of firms and the equilibrium quantities required when defining the per-unit subsidy needed to promote the non-subsidisation profits in equilibrium.

---

[2] Such a mechanism is likely to be two dimensional in that two different signals must be offered. A delay signal gives only one piece of information and so allows the determination of either fixed or marginal costs but not both (unless fixed and marginal costs are related). A voluntary restriction of quantity may possibly act as a signal of marginal cost in equilibrium and fixed costs may be signalled by delay. A two dimensional signalling equilibrium is likely to be highly complex and is suggested as an avenue for future research.

[3] Drug characteristics are the λ and η for the distributions of each drug.

Woodfield, Fountain and Borren analyse a further case where there is an asymmetry between the firms in an industry. Firm one is given a greater share of the market at each shared price level. The demand functions for each firm are

$$X_1 = 12 - P_1 + 0.25P_2$$
$$X_2 = 8 - P_2 + 0.25P_1$$

In this case the unsubsidised Nash equilibrium has $P_1 = \$7.75$ and $P_2 = \$5.97$ with profits of 33 and 15.76 million dollars accruing to firms one and two, respectively. The following table outlines the results obtained where, in turn, no subsidies are offered, subsidies are offered to one firm only and where both firms are subsidised up to their original levels of profit.

	No subsidies	Firm 1 subsidised	Firm 2 subsidised	Both firms subsidised
Firm 1				
P_1	\$ 7.75	\$ 4.92	\$ 7.25	\$ 5.14
P_1^e	\$ 7.75	\$ 2.00	\$ 7.25	\$ 2.00
X_1	5.75 m	11.30 m	5.25 m	10.50 m
π_1	\$ 33.00 m	\$ 33.00 m	\$ 27.56 m	\$ 33.00 m
Firm 2				
P_2	\$ 5.97	\$ 5.25	\$ 4.00	\$ 4.42
P_2^e	\$ 5.97	\$ 5.25	\$ 2.00	\$ 2.00
X_2	3.97 m	3.25 m	7.81 m	6.50 m
π_2	\$ 15.76 m	\$ 10.56 m	\$ 15.76 m	\$ 15.76 m
cost of scheme	\$ 0.00 m	\$ 33.00 m	\$ 17.56 m	\$ 48.76 m

Table 7.1: Results of the subsidy game.

It was observed that, as a cost-containing agency, Pharmac is likely to opt for offering a subsidy only to firm two in the above example. Here the agency can limit the cost of providing pharmaceuticals in this group to only \$15.76 million by intentionally bypassing the higher quality option. Option four gives a better outcome again with a cost tag of \$38.12 million to the taxpayer. Under option four $P_1 = P_2 = \$2$, $s_1 = \$2.62, s_2 = \$1.62$, $\pi_1 = \$27.56\text{m}, \pi_2 = \$10.56\text{m}$. The government gains over \$10 m when it utilises its strategic advantage.

Woodfield *et al* extend this example to outline the costs of providing pharmaceuticals at zero cost where marginal costs are significant. The $48.76 million dollars option four costs is vastly outweighed by the $124 million dollars a zero price scheme would involve.

II. RESULTS UNDER THE PHARMACEUTICAL MARKET MODEL

The application of the general framework defined in the report of Johnston and Zeckhauser to the pharmaceutical market model is a relatively simple matter. Four cases need to be isolated to determine the payoff matrix in the game where each firm decides whether or not to accept an offer of subsidisation. The benchmark case of an unregulated duopoly where no subsidies are offered is the first of the four cases required. The profits of each firm under the unregulated duopoly are labelled $\pi_1^{ns,ns}$ and $\pi_2^{ns,ns}$ for firms 1 and 2 respectively.

The next two cases identified are where only one of the firms is subsidised. The profits of firm i in the situation where firm 1 is subsidised are labelled $\pi_i^{s,ns}$. The corresponding profits where firm 2 is the only subsidised firm are labelled as $\pi_i^{ns,s}$.

Using option four of the Johnston and Zeckhauser report each firm is offered the profits that would accrue to it if it were not to join the scheme (plus an epsilon), conditional on the choice of their competitor.

		Firm 2	
		join scheme	stay out
Firm 1	join scheme	$\pi_1^{ns,s}+\varepsilon_1,\ \pi_2^{s,ns}+\varepsilon_2$	$\pi_1^{ns,ns}+\varepsilon_1,\ \pi_2^{s,ns}$
	stay out	$\pi_1^{ns,s},\ \pi_2^{ns,ns}+\varepsilon_2$	$\pi_1^{ns,ns},\ \pi_2^{ns,ns}$

Figure 7.2: General form of the subsidy game.

As observed earlier the subsidy game is a prisoners' dilemma problem with the dominant strategy equilibrium {join, join}. Under marginal cost pricing firms will be paid a per-unit subsidy for participation that recoups the profits they would otherwise have made, with a small

epsilon possibly added. Consumer prices in this variant of the scheme equal marginal cost and producer prices are found by calculation where:

$$p_1 = c_1 + \pi_1^{ns,s} / \mu_1(c_1, c_2)$$
$$p_2 = c_2 + \pi_2^{s,ns} / \mu_2(c_1, c_2)$$

Producer prices equal marginal cost plus the per-unit premium required to provide them with their non-participation profits.

The zero price variant of the JZ scheme was found in a like manner in that consumer prices are zero and producer prices are just sufficient to allow a recouping of non-participation profits.

$$p_1 = c_1 + \pi_1^{ns,s} / \mu_1(0,0)$$
$$p_2 = c_2 + \pi_2^{s,ns} / \mu_2(0,0)$$

Note that producer prices under the zero price variant of the JZ scheme are expected to be lower for two reasons. The non-participation profits of firms will differ in each case with smaller profits being available under the zero price case because an unsubsidised firm generally faces a lower consumer price. Quantities consumed in equilibrium in the zero price case will also be higher, leading to a lower premium being required under the zero price outcome than marginal cost pricing and lower producer prices generally.

The zero price and marginal cost price outcomes for the JZ scheme have been calculated for each of the cases explored in chapter 6 and tables updating those found in the previous chapter are displayed in the following sections.

(1) Identically distributed drugs

The previous chapter found that reference pricing was superior to an unregulated duopoly where taxes are non-distortionary. In each of the four cases examined marginal cost provision was more efficient than either reference pricing or the unsubsidised framework in the non-distortionary case but not necessarily cheaper. Since the costs of provision of this scheme were not known nothing could be said regarding its suitability in terms of efficiency or expense when taxes are distortionary.

For the case of identically distributed drugs the above framework has allowed for examination of both zero and marginal cost provision of pharmaceuticals. The results are summarised in the following tables reproduced from the previous chapter with the additional information in bold type.

	p_1	p_2	p_1^c	p_2^c	μ_1 (m)	μ_2 (m)	μ_N	π_1	π_2
Unregulated duopoly	2.95	2.95	2.95	2.95	0.28	0.28	0.44	0.55	0.55
RP (zero charge - high)	6.00	6.00	0.00	0.00	0.43	0.43	0.14	2.16	2.16
RP (zero charge - low)	4.81	4.81	0.00	0.00	0.43	0.43	0.14	1.64	1.64
JZ (zero charge)	**1.70**	**1.70**	0.00	0.00	0.43	0.43	0.14	**0.30**	**0.30**
RP (MC charge - high)	6.00	6.00	1.00	1.00	0.40	0.40	0.20	2.00	2.00
RP (MC charge - low)	4.32	4.32	1.00	1.00	0.40	0.40	0.20	1.32	1.32
JZ (MC charge)	**1.93**	**1.93**	1.00	1.00	0.40	0.40	0.20	**0.37**	**0.37**

	p_1	p_2	p_1^c	p_2^c	*consumer surplus*	*subsidy cost*	*total surplus*	*total surplus (10% DWL)*
Unregulated duopoly	2.95	2.95	2.95	2.95	\$0.6534 m	\$0.0000 m	\$1.7437 m	\$1.7437 m
RP (zero charge - high)	6.00	6.00	0.00	0.00	\$2.8383 m	\$5.1880 m	\$1.9737 m	\$1.4549 m
RP (zero charge - low)	4.81	4.81	0.00	0.00	\$2.8383 m	\$3.2926 m	\$1.9737 m	\$1.6444 m
JZ (zero charge)	**1.70**	**1.70**	0.00	0.00	\$2.8383 m	**\$1.4695 m**	\$1.9737 m	**\$1.8268 m**
RP (MC charge - high)	6.00	6.00	1.00	1.00	\$2.0047 m	\$3.9905 m	\$2.0047 m	\$1.6057 m
RP (MC charge - low)	4.32	4.32	1.00	1.00	\$2.0047 m	\$2.6499 m	\$2.0047 m	\$1.7397 m
JZ (MC charge)	**1.93**	**1.93**	1.00	1.00	\$2.0047 m	**\$0.7338 m**	\$2.0047 m	**\$1.9313 m**

Table 7.2: Identically distributed drugs.

Where the quality of two drugs are distributed independently along identical distributions the JZ schemes are far superior to reference pricing. The marginal cost of provision of a drug under reference pricing may be up to 350% of the figure predicted from the JZ scheme. The superiority holds both where zero and marginal cost prices are charged to patients. This difference is more emphatic under zero pricing, where the predicted range of shared prices encompasses a higher range and the JZ scheme demands a smaller price. With far lower payments necessary to firms under the JZ scheme the distortionary effects of raising subsidies be smaller. Either Johnston and Zeckhauser variant is more efficient than the unregulated duopoly situation under comparisons where distortions of 10% are accounted for.

Marginal cost pricing is a superior option for the government in this case because it gives a better outcome for both the taxpayer and the economy at large. When comparing the variants of the JZ scheme differences in both the volume of treatment and the cost of subsidisation must be taken into account. Total treatment under zero pricing would see 60,000 more people treated

(6% of total) but would see the profits of each firm fall.[4] The cost of the zero price scheme is $1.47 m to the taxpayer of which of $0.86 m is compensation to producers for production costs and $0.60 m in profits. Consumer surplus and efficiency would be as for the reference pricing case in a world with non-distortionary taxes.

The following diagram illustrates the difference in producer prices between the schemes. The range of equilibria expected under the reference pricing variants is graphed along with the expected points under both the unregulated case and JZ outcomes. The prices under reference pricing are demonstrably larger than under its alternatives. The large reduction in producer prices when moving from an unregulated position to the JZ can also be seen.

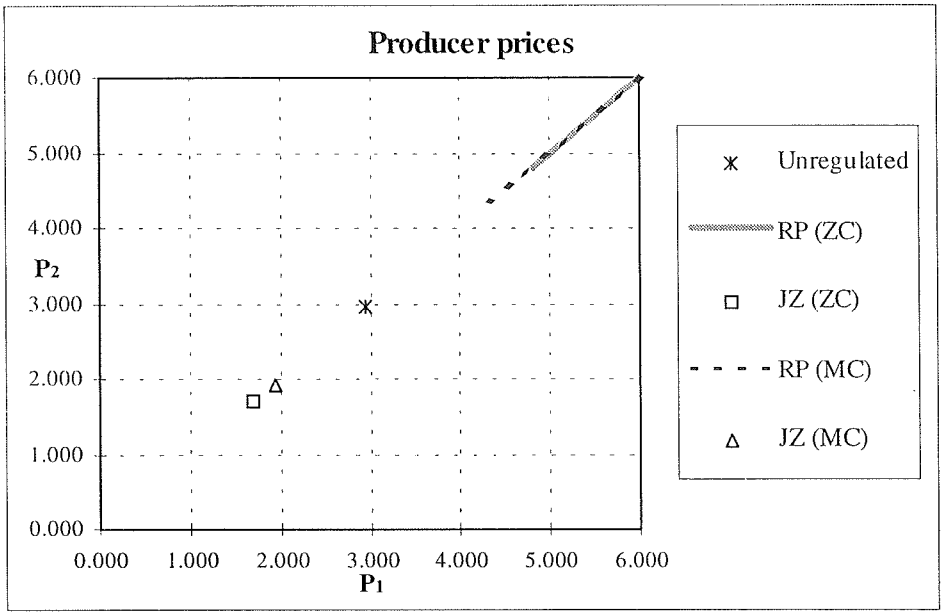


Figure 7.3: Comparison of producer prices (identically distributed drugs).

(2) Large asymmetry in efficacy

Where a large difference exists in the efficacy of two independent drugs the JZ schemes are once more superior to both reference pricing and the unregulated duopoly case. Producer prices and profits are again lowest under the marginal cost scheme.

[4] Since their non-participation profits would have also fallen since when not participating in the scheme they face a competitor with a price of $0.00 rather than $1.00.

	p_1	p_2	p_1^c	p_2^c	μ_1 (m)	μ_2 (m)	μ_N	π_1	π_2
Unregulated duopoly	3.15	1.75	3.15	1.75	0.30	0.10	0.59	0.65	0.08
RP (zero charge)	6.63	6.00	0.63	0.00	0.53	0.22	0.25	2.98	1.09
JZ (zero charge)	**1.85**	**1.22**	0.00	0.00	0.59	0.19	0.22	**0.50**	**0.04**
RP (MC charge)	6.21	6.00	1.00	1.00	0.53	0.14	0.33	2.65	0.71
JZ (MC charge)	**2.06**	**1.87**	1.00	1.00	0.53	0.14	0.33	**0.49**	**0.20**

	p_1	p_2	p_1^c	p_2^c	*consumer surplus*	*subsidy cost*	*total surplus*	*total surplus (10% DWL)*
Unregulated duopoly	3.15	1.75	3.15	1.75	\$0.3420 m	\$0.0000 m	\$1.0681 m	\$1.0681 m
RP (zero charge)	6.63	6.00	0.63	0.00	\$1.7233 m	\$4.4818 m	\$1.3093 m	\$0.8612 m
JZ (zero charge)	**1.85**	**1.22**	0.00	0.00	\$2.0742 m	**\$1.3170 m**	\$2.0742 m	**\$1.9425 m**
RP (MC charge)	6.21	6.00	1.21	1.00	\$1.2397 m	\$3.2646 m	\$1.2397 m	\$0.9132 m
JZ (MC charge)	**2.06**	**1.87**	1.00	1.00	\$1.3485 m	**\$0.6956 m**	\$1.3485 m	**\$1.2789 m**

Table 7.3: Asymmetry in efficacy.

Efficiency is once more highest under the JZ marginal cost scheme whether distortions are assumed to be zero or 10%. Where patients are charged at marginal reference pricing costs over four and a half times as much as the JZ scheme. Since firm one decides to charge at a premium in this case the nomenclature of the RP schemes is slightly misleading since patients purchasing drug 1 face the set charge (0 or 1) plus a differential (0.63 or 0.21 for the zero or marginal cost charge schemes respectively). The lower prices of the JZ scheme lead to higher levels of consumer surplus while costing only a third as much as the reference pricing scheme. Implementation of the JZ scheme as opposed to reference pricing would appear to ultimately lower the pharmaceutical bill.

As with the previous case the producer prices of the firms under the reference pricing (RP) and JZ schemes have been plotted below. The reaction curves of both firms in the unregulated position are also given in Figure 7.4.

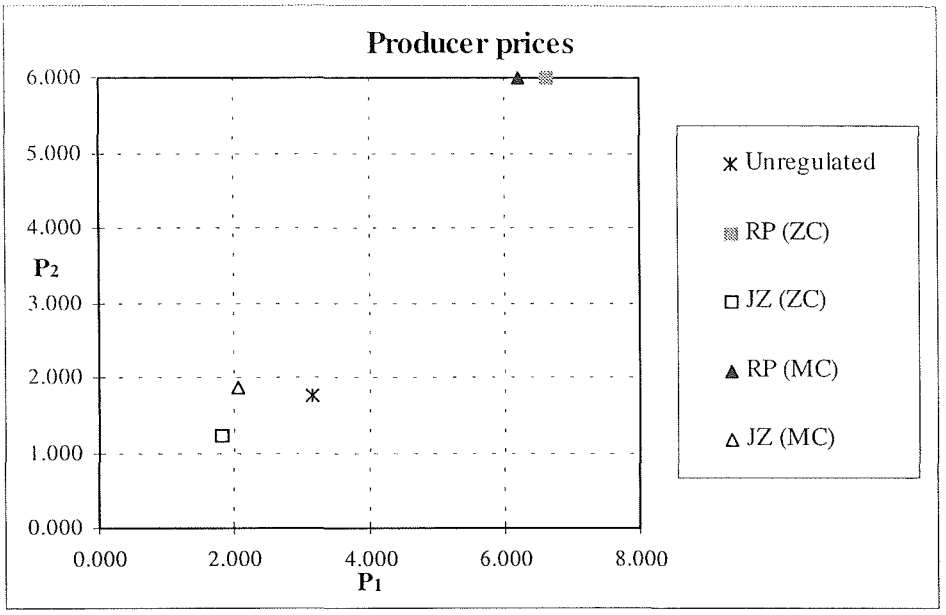


Figure 7.4: Comparison of producer prices (asymmetry in efficacy).

Note that the producer price of firm two in JZ (MC) is higher than under the unregulated case. This is not a result of the marginal cost scheme providing little impetus to keep prices low but rather it reflects the very low quantity of the low quality drug used when firms price at marginal cost. In order to compensate firm 2 for even the low level of profits it attains the per unit subsidy must be high.

(3) Large asymmetry in risk

The case where drug 1 has an average side effect of only 20% of that of drug 2 promotes the lowest priced RP outcome of the four cases considered. Accordingly it would seem that it has the best chance of gaining a superior outcome to the JZ scheme. Unfortunately for proponents of reference pricing it fares no better under this scheme in comparison to the JZ scheme than did any other case. The summary table is given below.

	p_1	p_2	p_1^c	p_2^c	μ_1 (m)	μ_2 (m)	μ_N	π_1	π_2
Unregulated duopoly	3.42	2.71	3.42	2.71	0.61	0.26	0.13	1.49	0.44
RP (zero charge)	5.59	4.10	1.48	0.00	0.61	0.38	0.01	2.80	1.18
JZ (zero charge)	**2.04**	**1.13**	0.00	0.00	0.83	0.17	0.00	**0.86**	**0.02**
RP (MC charge)	5.05	3.79	2.26	1.00	0.62	0.35	0.03	2.53	0.97
JZ (MC charge)	**2.28**	**1.29**	1.00	1.00	0.83	0.17	0.01	**1.06**	**0.05**

	p_1	p_2	p_1^c	p_2^c	*consumer surplus*	*subsidy cost*	*total surplus*	*total surplus (10% DWL)*
Unregulated duopoly	3.42	2.71	3.42	2.71	\$1.0114 m	\$0.0000 m	\$2.9362 m	\$2.9362 m
RP (zero charge)	5.59	4.10	1.48	0.00	\$3.1056 m	\$4.0597 m	\$3.0222 m	\$2.6162 m
JZ (zero charge)	**2.04**	**1.13**	0.00	0.00	\$4.1687 m	**\$1.8843 m**	\$4.1687 m	**\$3.9803 m**
RP (MC charge)	5.05	3.79	2.26	1.00	\$2.2610 m	\$2.7097 m	\$2.2610 m	\$1.9900 m
JZ (MC charge)	**2.28**	**1.29**	1.00	1.00	\$3.1735 m	**\$1.1044 m**	\$3.1735 m	**\$3.0631 m**

Table 7.4: Asymmetry in risk.

Producer prices are again lowest under both JZ schemes leading to a far smaller subsidy cost. Once more the superior firm chooses to price at a premium under reference pricing imposing a large cost on consumers under each variant. Efficiency is once more higher under the JZ scheme than its alternatives at 0 and 10% levels of DWL resulting from taxation. Figure 7.5, as with its predecessors, presents the prices of the alternative schemes in a graphical form, showing that the marginal cost pricing scheme results in producer prices far smaller than the other options addressed.

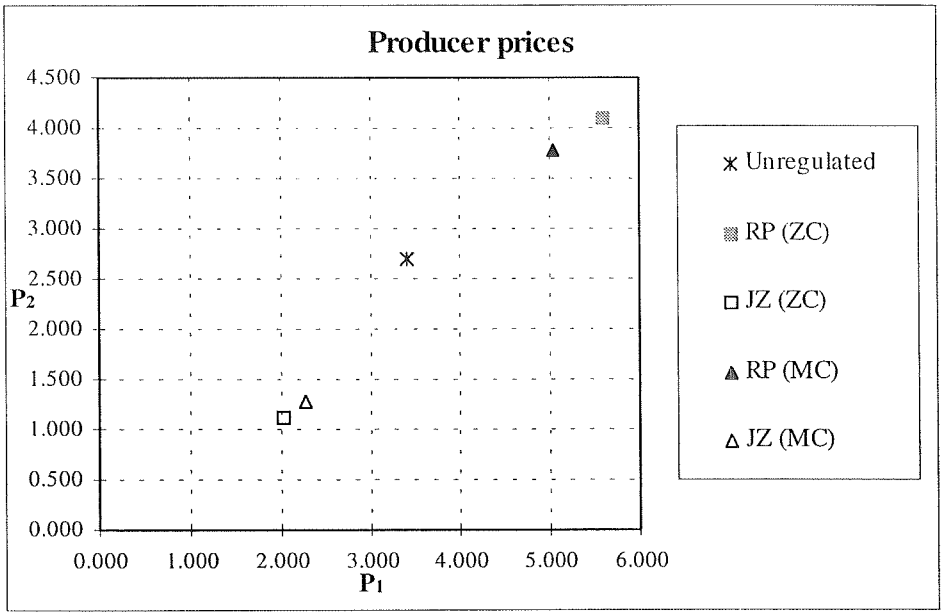


Figure 7.5: Comparison of producer prices (asymmetry in risk).

(4) Balanced asymmetry

The final case addressed deals with a situation where two drugs are generally balanced in their qualities. Drug 1 has a lower efficacy than drug 2 but a higher degree of predictability. The amended results table for this scenario is given below.

	p_1	p_2	p_1^c	p_2^c	μ_1 (m)	μ_2 (m)	μ_N	π_1	π_2
Unregulated duopoly	2.61	2.73	2.61	2.73	0.25	0.26	0.49	0.41	0.44
RP (zero charge - high)	6.00	6.00	0.00	0.00	0.41	0.43	0.16	2.07	2.13
RP (zero charge - low)	4.51	4.51	0.00	0.00	0.41	0.43	0.16	1.46	1.50
JZ (zero charge)	**1.57**	**1.59**	0.00	0.00	0.41	0.43	0.16	**0.24**	**0.25**
RP (MC charge - high)	6.00	6.00	1.00	1.00	0.37	0.39	0.24	1.86	1.93
RP (MC charge - low)	3.91	3.91	1.00	1.00	0.37	0.39	0.24	1.08	1.12
JZ (MC charge)	**1.78**	**1.81**	1.00	1.00	0.37	0.39	0.24	**0.29**	**0.31**

	p_1	p_2	p_1^c	p_2^c	*consumer surplus*	*subsidy cost*	*total surplus*	*total surplus (10% DWL)*
Unregulated duopoly	2.61	2.73	2.61	2.73	\$0.4883 m	\$0.0000 m	\$1.3408 m	\$1.3408 m
RP (zero charge - high)	6.00	6.00	0.00	0.00	\$2.3714 m	\$5.0423 m	\$1.5310 m	\$1.0267 m
RP (zero charge - low)	4.51	4.51	0.00	0.00	\$2.3714 m	\$2.9520 m	\$1.5310 m	\$1.2358 m
JZ (zero charge)	**1.57**	**1.59**	0.00	0.00	\$2.3714 m	**\$1.3278 m**	\$1.5310 m	**\$1.3982 m**
RP (MC charge - high)	6.00	6.00	1.00	1.00	\$1.5697 m	\$3.7854 m	\$1.5697 m	\$1.1912 m
RP (MC charge - low)	3.91	3.91	1.00	1.00	\$1.5697 m	\$2.2005 m	\$1.5697 m	\$1.3497 m
JZ (MC charge)	**1.78**	**1.81**	1.00	1.00	\$1.5697 m	**\$0.6014 m**	\$1.5697 m	**\$2.1047 m**

Table 7.5: Balanced asymmetry.

As with the previous three cases this example supports the JZ scheme as a cheaper and more efficient method of subsidisation than reference pricing. Figure 7.6 visually compares the prices expected under each scheme. Table 7.5 suggests that the price of marginal cost provision is at best 26%, and at worst only 47%, of the cost of reference pricing.

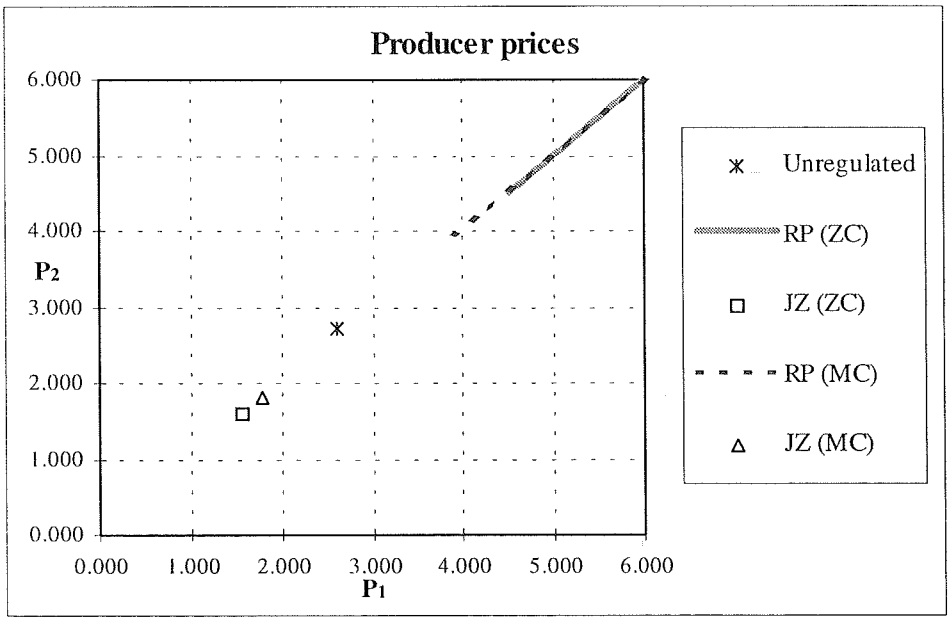


Figure 7.6: Comparison of producer prices (balanced asymmetry).

As with previous diagrams Figure 7.6 shows the gulf between the alternative schemes. In all four cases reference pricing has ineffectively contained prices compared with the alternative JZ scheme.

(5) Conclusions

Marginal cost pricing appears to be a superior form of subsidisation than reference pricing where all relevant information is known by the funding agency. The alternative scheme is less costly than reference pricing while efficiency considerations favour the former scheme at both addressed levels of tax distortion.[5] Given the availability of the JZ scheme the use of reference pricing is inefficient if information is freely available.

In reality commercially sensitive information such as the cost structure of a firm is not freely available. For an accurate comparison between different schemes the information that firms have is highly important. The pertinent items of information that Pharmac would require, if marginal cost pricing is to be used are as follows: For every firm in the target subgroup Pharmac must know the characteristics of all drugs (λ_i, η_i) and the cost function of the firm with respect to the target drug.[6]

Of these two items of information the former is possibly easier to find since every drug applying for listing on the Pharmaceutical Schedule must include data as to its efficacy and side effects.

Information regarding the cost functions of drug companies is unlikely to be freely given. Drug companies, if given a choice of the price they receive will naturally choose the highest possible price and would manipulate the information they report to Pharmac in order to make

---

[5] Since it is superior at zero distortion and costs less than reference pricing.

[6] The characteristics of drug quality distributions define the demand functions for each firm. The alternative for Pharmac would be to either estimate the cost function or to use average marginal cost in order to find the relevant JZ subsidy. Either approach would be troublesome. As the JZ scheme only just promotes enough profit to make a firm indifferent over participating in the scheme, any underestimation of the marginal cost of the firm, regardless of how small, will result in no subsidisation. Where the estimated cost is an unbiased estimator of true marginal cost subsidisation will fail to be achieved approximately half the time. Where average cost is used the same problem will occur, here occurring exactly half the time.

sure they receive it. The discovery of information of this type has been addressed by literature on delays in bargaining and is summarised in Chapter 9. In these models of information discovery the future profit stream of each firm is taken into account. The profits accruing to a firm occur both during and after patent protection. The expiration of patent protection and, more specifically the effect of the introduction of generics into the market must be addressed. Unless the effects of generics are known the multi-period profit function remains unknown and nothing can be said about models promising to reveal information. For this reason the following chapter addresses the issue of generics.

CHAPTER 8

GENERIC ENTRY INTO A DIFFERENTIATED MARKET

A patent is issued for 20 years in New Zealand. When determining the multi period profit ınction required in the following chapter the effects on a firm of the expiration of patent rotection must first be known. This chapter attempts to introduce what is meant by a generic rug in the context of the pharmaceutical market model and what it means for the profits chieved for the formerly protected firm. Since pharmaceuticals do not enter the market at the me of patenting Section IV addresses the delays to market and the effective patent life of harmaceuticals in New Zealand.

The problems associated with the removal of the search component of the pharmaceutical narket model are strongest when dealing with generic drugs. Established drugs, by nature of heir longer time in the market, may have accumulated a substantial reputation by the time ıatents expire. The reputation of the generic must likewise be built over time as its true quality is liscovered slowly. The assumption that individual qualities are known by all patients leads to a greater share of the market going to generic drugs than is likely under a search framework. This lifference in market share between new and existing drugs will occur irrespective of whether any lifferences exist between any drug and its generic copies.

. DEFINITIONS

In the pharmaceutical market model the quality of drugs have been assumed to fall ndependently along predefined distributions. This assumption is modified in the case of generic drugs. Generic drugs are taken to be pharmaceuticals for which quality is a deterministic function of the quality of another drug. For an individual, knowledge of the original drug's quality (drug i) also gives the knowledge of the quality of the copy/generic drug (drug k).

$$\varphi_{kj} = H(\varphi_{ij})$$

It is envisaged that generic drugs will include the same active ingredient(s) as the original ug but may differ in efficacy and/or the level of side effects.[1] Generic drugs are expected to be ıarmaceutically equivalent[2] but not necessarily bioequivalent[3] to their innovative cousins.

The natural way to relate the quality distribution of the original drug with the quality stribution of the generic is through the cumulative distribution of each drug. An drug is said to ɜ a generic copy if individuals fall in the same position along the cumulative distributions of ıch drug.[4] For individual j facing drug i and its generic copy k:

$$
\begin{aligned}
F_i(\varphi_{ij}) &= F_k(\varphi_{kj}) \\
e^{-\eta_i(\varphi_{ij}-\lambda_i)} &= e^{-\eta_k(\varphi_{kj}-\lambda_k)} \\
\eta_i(\varphi_{ij}-\lambda_i) &= \eta_k(\varphi_{kj}-\lambda_k) \\
\eta_i\varphi_{ij}-\eta_i\lambda_i &= \eta_k\varphi_{kj}-\eta_k\lambda_k \\
\eta_i\varphi_{ij}-\eta_i\lambda_i+\eta_k\lambda_k &= \eta_k\varphi_{kj} \\
\eta_i\varphi_{ij}-\eta_i\lambda_i+\eta_k\lambda_k &= \eta_k\varphi_{kj} \\
\varphi_{kj} &= \lambda_k-\frac{\eta_i}{\eta_k}(\lambda_i-\varphi_{ij})
\end{aligned}
$$

So that the quality of drug k is a deterministic function of the quality of drug i. The ɜlationship between two drugs connected by an equality of positions in the cumulative density unction of each drug is displayed graphically below.

---

[1] This difference may be due to manufacturing standards or differences in inactive ingredients.

[2] Pharmaceutically equivalent drugs must meet the same standards of quality as well as contain the ame active ingredients in the same form and the same dosage. (Source: Therapeutics Section, Ministry ɔf Health. (1994) *Interchangeable Multi-source Medicines.* Ministry of Health. p.vii)

[3] Bioequivalence requires pharmaceutical equivalence in addition to the following:

- bioavailabilities are administration in the same molar dose are similar to such a degree that their effects with respect to both efficacy and safety will essentially be the same
- they present no known or potential problems of bio-inequivalence and they meet a relevant *in-vitro* standard.

(Source: Therapeutics Section, Ministry of Health. (1994) *Interchangeable Multi-source Medicines.* Ministry of Health p.vii)

[4] As the quality of the generic is perfectly predictable given the quality of the initial drug, the ɜffects of switching between drugs is known. This may not be particularly realistic but, given that partial dependence would be very challenging algebraically, it appears to be the best available assumption.

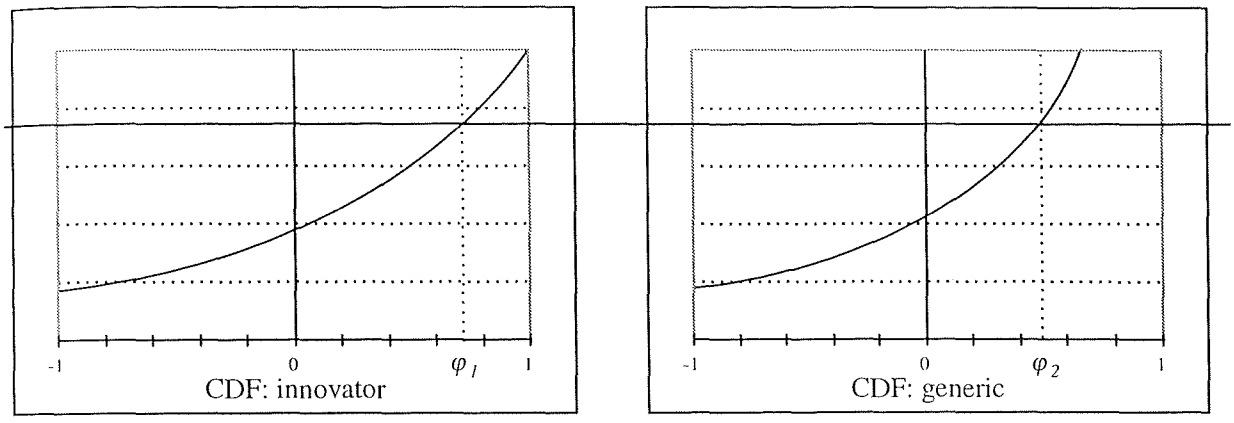


Figure 8.1: Graphical representation of generic relationship

These diagrams represent the cumulative density functions of an innovative drug and its eneric copy. A patient here is identified as occupying a position on the innovative drug's CDF o that the individual specific quality faced for the generic drug is simply the quality at which the inctions take the same value.

Differences between drugs can occur in both differences in efficacy and risk. The ollowing sections describe the effects on the decisions of firms in each case and the potential for ncorporating this type of difference into the pharmaceutical market model.

I. DIFFERENCES IN EFFICACY

The following sections describe the effects on the decisions of firms in each case and the otential for incorporating this type of difference into the pharmaceutical market model.

(1) A two firm example

Of the types of potential differences between generic drugs and their original counterparts a difference in efficacy is the conceptually simpler option since here every patient faces the same difference in quality between treatment options. It was previously shown that the relationship

tween the qualities of two generically related drugs is assumed to satisfy the following uation:

$$F_i(\varphi_{ij}) = F_k(\varphi_{kj})$$

$$\varphi_{kj} = \lambda_k - \frac{\eta_i}{\eta_k}(\lambda_i - \varphi_{ij})$$

$$\varphi_{kj} = \varphi_{ij} + (\lambda_k - \lambda_i)$$

A difference in efficacy between two drugs is perceived by patients as a fixed difference in e quality of the drugs. Drug 2 will be chosen in preference to drug 1 by all consumers if:

$$U_{treatment_1} > U_{treatment_2}$$

$$L\varphi_2 - p_2 > L\varphi_1 - p_1$$

$$L(\varphi_1 + \lambda_2 - \lambda_1) - p_2 > L\varphi_1 - p_1$$

$$L\varphi_1 + L\lambda_2 - L\lambda_1 - p_2 > L\varphi_1 - p_1$$

$$L\lambda_2 - L\lambda_1 > p_2 - p_1$$

$$p_2 < p_1 + L\lambda_2 - L\lambda_1$$

Likewise drug 1 will be chosen in preference to drug 2 by all consumers when $_1 < p_2 + L\lambda_1 - L\lambda_2$.

If each drug is to have a positive share of the market then neither of the above propositions an be true and so:

$$p_1 - p_2 = L\lambda_1 - L\lambda_2$$

$$\frac{(p_1 - p_2)}{L} = \lambda_1 - \lambda_2$$

If an equilibrium exists with both firms charging above marginal cost then $\frac{(p_1 - p_2)}{L} = \lambda_1 - \lambda_2$.[5] n this situation each firm would have an incentive to decrease price by an epsilon and gain the ntire market. Prices would be driven down through this mechanism until one or both of the irms no longer have an incentive to undercut. The final situation is sensitive to the relative sizes of the cost asymmetry between firms and the asymmetry in efficacy between each of the drugs. Taking drug 1 to be the incumbent pharmaceutical and drug 2 to be its generic copy it is expected hat the generic drug will have a cost advantage over the incumbent and that the efficacy of firm l is at least as great as that of drug 2.

[5] The value of the asymmetry is the differential $L(\lambda_2 - \lambda_1)$ it allows the superior firm to charge.

The contributions that the incumbent firm must make to its parent company to assist in the osts of research and development will increase the costs of the drug to the firm.[6] The generic rm will bear no such cost and so the generic is expected to have a cost advantage over the firm $c_1 > c_2$).

The drug of the incumbent firm is expected to have efficacy at least as great as that of the eneric copy. Through years of experience in researching, developing and producing the drug ıe incumbent is likely to have gained greater knowledge of the properties in the active ıgredients of the pharmaceutical. With greater experience may well come greater expertise and o a superior level of efficacy is expected in the incumbent firm's drug ($\lambda_1 > \lambda_2$).

If the cost disadvantage of firm 1 equals the value of the incumbent's advantage in efficacy : is expected that both firms will produce at marginal cost and both firms will take a positive hare of the market. Here $L(\lambda_1 - \lambda_2) = c_1 - c_2$, $p_1 = c_1$ and

$$\begin{aligned} p_2 &= p_1 + L\lambda_2 - L\lambda_1 \\ &= c_1 - L(\lambda_1 - \lambda_2) \\ &= c_1 - (c_1 - c_2) \\ &= c_2. \end{aligned}$$

Where the cost disadvantage of firm 1 outweighs the value of the incumbent's advantage in :fficacy firm 1 cannot compete in equilibrium. The unique pure strategy equilibrium in this case ees firm 1 pricing at marginal cost and firm 2 undercutting by an epsilon (once the value of the :fficacy differential has been removed). Here $p_1 = c_1$, $L(\lambda_1 - \lambda_2) < c_1 - c_2$ so that

$$\begin{aligned} p_2 &= c_1 - L(\lambda_1 - \lambda_2) \\ &> c_1 - (c_1 - c_2) \\ &= c_2. \end{aligned}$$

Firm two charges above marginal cost and takes the entire market. Neither firm has an ncentive to change its price, making this outcome an equilibrium. This outcome is the only

---

[6] It appears reasonable that the parent company will charge larger users of their patented drug a arger charge than smaller users. The larger is the market share of the drug, the more of the drug is used ınd the greater are the contributions that the New Zealand subsidiary must pay towards the parent's :esearch. That these contributions increase in quantity leads to an increase in the incremental cost of lrug production.

ash equilibrium because where firm 1 prices above c_1 firm 2 has an incentive to increase its ice to just over this level and firm 1 will never price below c_1.

Where the efficacy advantage of drug 1 outweighs its cost disadvantage the opposite enario to the above is expected. Firm 2 will price its product at marginal cost with drug 1 iced at an epsilon below the efficacy adjusted price. Drug 1, as shown below, will price above s marginal cost and attract the entire market. Here $p_2 = c_2$ and $L(\lambda_1 - \lambda_2) > c_1 - c_2$ so that

$$\begin{aligned} p_1 &= c_2 + L(\lambda_1 - \lambda_2) \\ &> c_2 + (c_1 - c_2) \\ &= c_1. \end{aligned}$$

The outcome of a two drug subgroup involving both a drug and it's generic clone depends rimarily on the relative sizes of the differences in cost and quality between the drugs. The firm ı the more advantageous position obtains the entire market.[7]

(2) Incorporation into the standard pharmaceutical market model

The incorporation of the third (generic) firm into the pharmaceutical market model is a latively simple process. The game between the firm with the copied drug and its generic ompetitor leads to very low prices that will remain optimal even with the addition of another irm. The price of the second firm will simply be their optimal reaction to the firm(s) surviving ıe game between the other two firms.

The effect of competition between the original drug and its generic equivalent is unchanged nder the addition of another firm.[8] The price of these two drugs in competition will fall until either firms has an incentive to decrease its price. Taking drugs 1 and 2 to be the incumbents nd drug 3 to be a generic copy of drug 1 the possible equilibrium situations can be identified.

---

[7] Since $L(\lambda_1 - \lambda_2) = c_1 = c_2$ will not generally hold one firm will limit price in equilibrium and ıus take the entire market.

[8] The only possible exception to this would be where the addition of another firm promotes an ıutcome where either the generic firm or the firm making the copied drug wishes to price substantially elow the level required to defeat its closest competitor. Since the prices observed under generic ompetition are far lower than those expected under the normal pharmaceutical market model it is very ınlikely that this will take place. The superior firm (given cost and quality differences) thus charges the naximum price it can while obtaining the entire market.

ote that drug 3, re-priced to remove the efficacy difference, is effectively identical to drug 1.[9] his allows the cases in Table 8.1 to be derived without reference to quantity functions different those of the two drug case:

cenario	Prices	Quantities
$(\lambda_1-\lambda_3)>c_1-c_3$	$p_1=c_3+L(\lambda_1-\lambda_3)$	$\mu_1=c_3+L(\lambda_1-\lambda_3)$
	$p_2=R_2(c_3+L(\lambda_1-\lambda_3))$	$\mu_2=\mu_2(c_3+L(\lambda_1-\lambda_3),R_2(c_3+L(\lambda_1-\lambda_3))$
	$p_3=c_3$	$\mu_3=0$
$(\lambda_1-\lambda_3)=c_1-c_3$	$p_1=c_1$	$\mu_1=\frac{1}{2}\mu_1(c_1,R_2(c_1))$
	$p_2=R_2(c_1)$	$\mu_2=\mu_2(c_1,R_2(c_1))$
	$p_3=c_3$	$\mu_3=\frac{1}{2}\mu_1(c_1,R_2(c_1))$
$(\lambda_1-\lambda_3)<c_1-c_3$	$p_1=c_1$	$\mu_1=0$
	$p_2=R_2(c_1)$	$\mu_2=\mu_2(c_1,R_2(c_1))$
	$p_3=c_1-L(\lambda_1-\lambda_3)$	$\mu_3=\mu_1(c_1,R_2(c_1))$

able 8.1: Observed outcomes under the PMM with a difference in generic efficacy.[10]

The above table allows for a simple analysis of the market after the entry of a generic firm. he simplicity of this model must be weighed against its unrealistic predictions. In reality we xpect that both the original drug and the generic will gain a positive market share in quilibrium. Where the original and generic drugs are differentiated only by a difference in fficacy the general outcomes of the pharmaceutical market model will see only one firm urviving.[11] The following section addresses the case of generics under the more realistic ssumption that allows for a difference in the safety of the generic drug. This difference in risk is onsidered in the following section.

II. DIFFERENCES IN RISK

[9] $\mu_3(p_2,p_3)=\mu_1(p_3+L(\lambda_1-\lambda_2),p_2)$ for cases where only firms 2 and 3 sell positive quantities.

[10] The shared market case assumes a 50% split of demand between the original and generic drugs. he table uses $\mu_1(p_1,p_2)$ and $\mu_2(p_1,p_2)$, the pre-generic demand functions and $R_2(p_1)$, the reaction unction of firm 2.

[11] Note that this result is highly sensitive to the assumption that individuals know the qualities they ace from every treatment option. Where drug qualities must be discovered both firms are expected to urvive in the market for a considerable time, even where drugs are differentiated an asymmetry in fficacy.

In the pharmaceutical market model quality is the difference between efficacy and an dividual specific side effect. Drugs that generally have a smaller individual specific side effect e characterised by a larger coefficient for η, the parameter of the exponential distribution side fects are drawn from. It is assumed that the original drug has a side effect profile at least as od as that of the generic drug. Where a difference in efficacy exists between drugs $\eta_1 > \eta_2$ here drug 1 is the original drug and drug 2 its generic competitor.[12]

Where drugs are perfectly correlated according to the cumulative density rule[13] and have a fference in risk the following is true

$$\varphi_1 = \lambda - \varepsilon_1 \qquad F_1(\varphi_1) = e^{\eta_1(\varphi_1 - \lambda)} = e^{\eta_1(\lambda - \varepsilon_1 - \lambda)} = e^{-\eta_1 \varepsilon_1}$$

$$\varphi_2 = \lambda - \varepsilon_2 \qquad F_2(\varphi_2) = e^{-\eta_2 \varepsilon_2}$$

id at an equivalent position in the CDF

$$F_1(\varphi_1) = F_2(\varphi_2)$$

$$e^{-\eta_1 \varepsilon_1} = e^{-\eta_2 \varepsilon_2}$$

$$\varepsilon_1 = \frac{\eta_2}{\eta_1} \varepsilon_2 .$$

The side effect for drug 1 is a constant fraction of that of drug 2. From this result general redictions on the type of patients choosing each drug can be ascertained. Since the original drug superior to its generic alternative it will charge a higher price in equilibrium.

For low side effects there will be very little difference between the quality of the drugs. atients facing a low side effect for both drugs will not choose drug 1 if they must pay a ubstantial premium for it. Patients facing a reasonably high side effects perceive a large ifference between the drugs and are likely to choose the original drug as the difference in quality utweighs the extra charge it attracts.

---

[12] The case where the two drugs have an identical side effect structure is relatively simple to nalyse. Such a case is equivalent to a simple Bertrand game which has the result of the lower cost rovider of the good servicing the entire market at a level of price slightly below the cost the next-best roducer can produce at. If both firms have the same cost structure the Bertrand game predicts that each vill charge at marginal cost and share the market.

[13] $F_i(\varphi_{ij}) = F_k(\varphi_{kj}) \quad \forall_{i,j,k}$.

If the side effect of drug 2 is ε then the quality of drug 1 is $\varphi_1 = \lambda - \frac{\eta_2}{\eta_1}\varepsilon$ and the quality of :ug 2 is $\varphi_2 = \lambda - \varepsilon$. For patients at the margin the gain in utility over the no treatment level[14] om using each treatment is equal. For these patients:

$$L\varphi_1 - p_1 = L\varphi_2 - p_2$$
$$L(\lambda - \tfrac{\eta_2}{\eta_1}\varepsilon) - p_1 = L(\lambda - \varepsilon) - p_2$$
$$L\lambda - L\tfrac{\eta_2}{\eta_1}\varepsilon - p_1 = L\lambda - L\varepsilon - p_2$$
$$L\varepsilon - L\tfrac{\eta_2}{\eta_1}\varepsilon = p_1 - p_2$$
$$\tfrac{\eta_1 - \eta_2}{\eta_1}\varepsilon = \tfrac{(p_1 - p_2)}{L}$$
$$\varepsilon = \tfrac{\eta_1}{\eta_1 - \eta_2}\tfrac{(p_1 - p_2)}{L}$$

Patients facing a side effect of below $\frac{\eta_1}{\eta_1 - \eta_2}\frac{(p_1 - p_2)}{L}$ for drug 2 will choose to use this drug /hereas patients facing $\varepsilon > \frac{\eta_1}{\eta_1 - \eta_2}\frac{(p_1 - p_2)}{L}$ will choose the superior drug 1. Where these firms rovide the only treatment options available the choices of each firm can be derived by appealing ɔ their profit functions. The continuation of this analysis is undertaken in Chapter 11, which riefly deals with an alternative view of the market for pharmaceuticals.

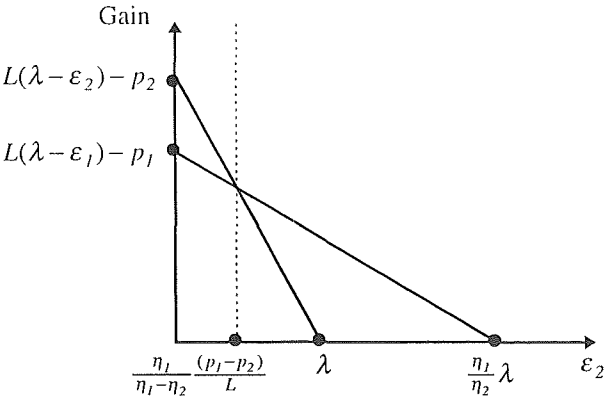


Figure 8.2: Gains from treatment ($\eta_1 > \eta_2$).

(1) Incorporation into the standard pharmaceutical market model

The introduction of a generic drug into the pharmaceutical market model is not a simple :ask in the case where drugs are differentiated with a difference in risk rather than efficacy. The :ase of a difference in efficacy can be compressed into two dimensions through appealing to the

[14] That is, *m-L*.

ame between the original drug and its generic copy. The decisions made in the risk-based case o not simplify in the same way so a more intensive analysis must be undertaken.

In Chapter 3 the pricing decision of a producer was analysed with the aid of a diagram owing the location of patients and the choices they make. Previously patients were located ccording to the qualities they faced of each drug. Geometrically location consisted of a vector $\Re^2$. The diagram below was used to give an explanation of which patients use each drug.

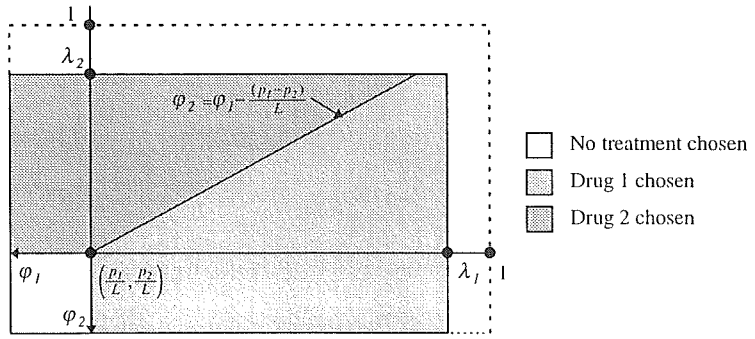


Figure 8.3: Treatment choice in a 2 drug setting

With the addition of another firm the vector of qualities a patient faces is now includes ree qualities and so must be plotted in $\Re^3$. As with the previous case the entire case cannot be onsidered so instead the area $\phi = \{\varphi_i > \text{?}/_L, \forall i = 1,2,3\}$ is addressed graphically.[15] Figure 8.4 displays e locations where consumers find that all three options are superior to taking no treatment.

[15] The decision between drugs outside of ϕ is considered once the treatment decisions of patients nside ϕ have been discussed.

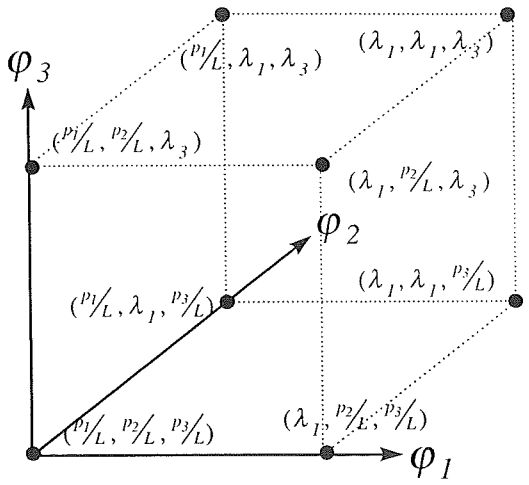


Figure 8.4: Patient locations.[16]

The above diagram does not include consideration of the relationship between drugs 1 and (the original and generic drugs respectively). It has already been established that where two rugs are perfectly predictable in terms of each other and differentiated only by a difference in de effects then $\varepsilon_1 = \frac{\eta_2}{\eta_1}\varepsilon_2$. This restricts the locations of the drugs 1 and 2 so that they must lie long the line displayed in the diagram below.

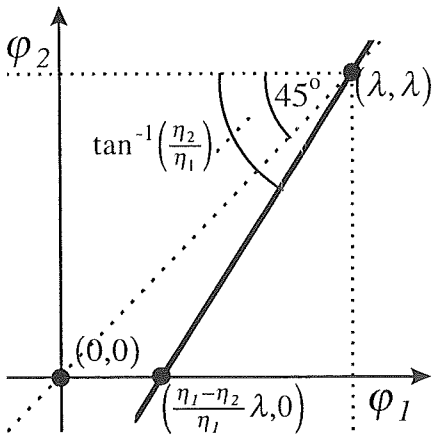


Figure 8.5: Related drugs ($\eta_1 > \eta_2$).

Note that one point on the above line must be at (λ_1, λ_1) where no side effects occur. The econd point above takes $\varepsilon_2 = \lambda_1$, so that $\varepsilon_1 = \frac{\eta_2}{\eta_1}\varepsilon_2 = \frac{\eta_2}{\eta_1}\lambda_1$ and the location is $\left(\frac{\eta_1-\eta_2}{\eta_1}\lambda_1, 0\right)$. When

[16] Recall $\lambda_1 = \lambda_2$ for drugs differentiated by risk alone.

otted in the three dimensional space of Figure 8.4 this line becomes the vertical plane as splayed on the following diagram.[17]

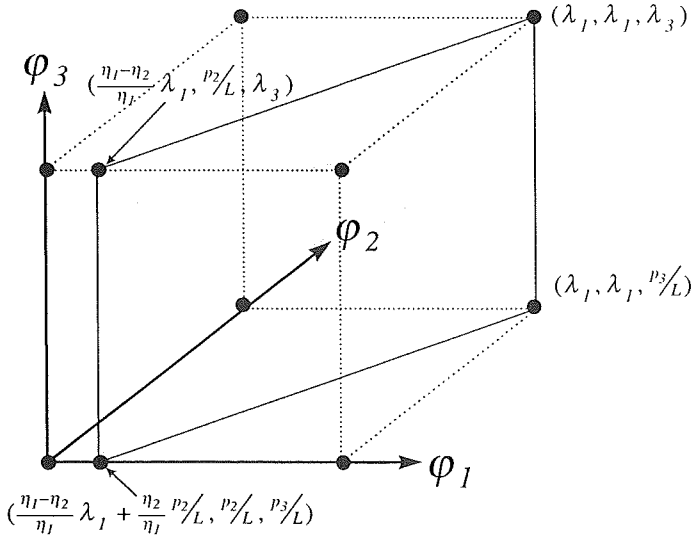


Figure 8.6: The φ_1-φ_2 plane.

Section III established that drug 1 is preferred where the side effect of drug 2 is at least as reat as $\frac{\eta_1}{\eta_1-\eta_2}\frac{(p_1-p_2)}{L}$. This result segments the above plane into the two regions where each drug used. A side effect of drug 2 of $\frac{\eta_1}{\eta_1-\eta_2}\frac{(p_1-p_2)}{L}$ implies that these patients face a side effect for rug 1 of $\frac{\eta_2}{\eta_1}\varepsilon = \frac{\eta_2}{\eta_1}\frac{\eta_1}{\eta_1-\eta_2}\frac{(p_1-p_2)}{L} = \frac{\eta_2}{\eta_1-\eta_2}\frac{(p_1-p_2)}{L}$. This preference relation is incorporated into the bove plane in Figure 8.7.

[17] Note that instead of zero as the value for the origin ${}^{p_i}\!/\!_L$ is again used. The point $\frac{\eta_1-\eta_2}{\eta_1}\lambda_1 + \frac{\eta_2}{\eta_1}{}^{p_3}\!/\!_L, {}^{p_2}\!/\!_L, {}^{p_3}\!/\!_L)$ was found through the relationship $\varepsilon_1 = \frac{\eta_2}{\eta_1}\varepsilon_2$. The diagram assumes that $\frac{1-\eta_2}{\eta_1}\lambda_1 + \frac{\eta_2}{\eta_1}{}^{p_3}\!/\!_L > {}^{p_3}\!/\!_L$. The counter assumption promotes a diagram where the plane cuts the φ_2 axis.

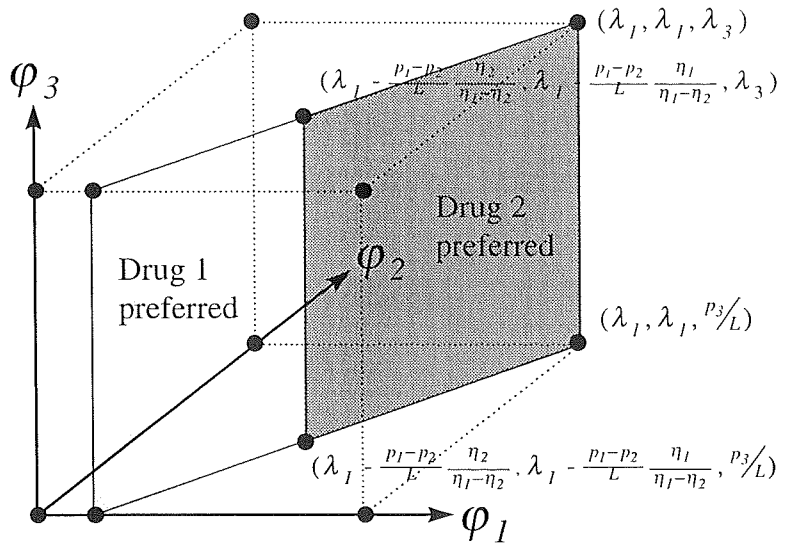


Figure 8.7: Preference relation (drug 1 - drug 2)

Drug i is preferred to drug j if the gain in utility from using drug i is greater than that btained from using drug j. The line representing marginal consumers between drugs i and j has lready been established for the case of two independent variables.[18] Marginal consumers are epresented by the equation $\varphi_i - \varphi_j = \frac{(p_i - p_j)}{L}$. In the two drug case this was represented by a line nd but the three drug case will be a plane parallel to the axis of the drug not considered in the airwise comparison. Using this equation the marginal consumers between firstly drugs 1 and 3, nd then drugs 2 and 3 can be derived and displayed. Taking the case of the preference elationship between drugs 1 and 3 we can obtain the following diagram.

[18] From Chapter 5.

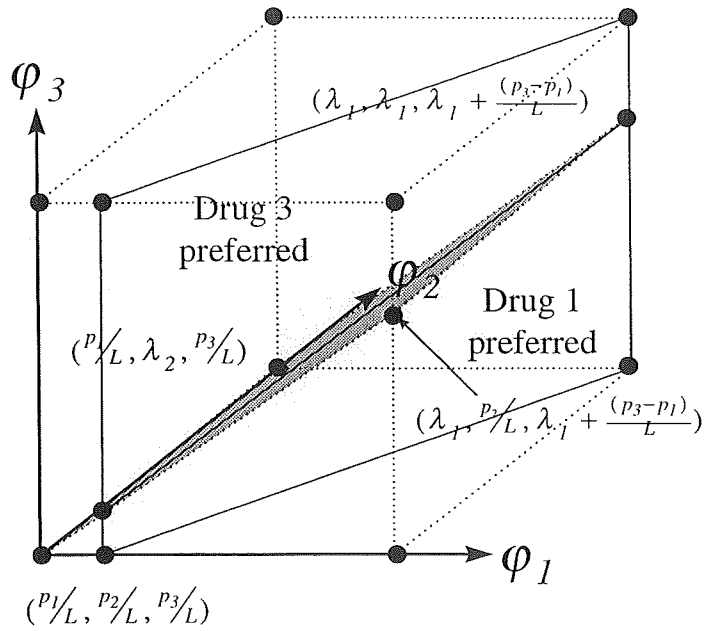


Figure 8.8: Marginal consumers and the location plane.

Where both drugs are only just of a high enough quality to justify treatment a patient must e indifferent between treatments. The origin of the above diagram must therefore constitute one oint on the darker shaded plane of marginal consumers above. Assuming that $\lambda_3 - \lambda_1 > \frac{(p_3-p_1)}{L}$, 'hen the quality of drug 1 equals λ_1 all patients facing a quality for drug 3 above $\lambda_1 + \frac{(p_3-p_1)}{L}$ will hoose the latter treatment option. The contrary assumption that $\lambda_3 - \lambda_1 \leq \frac{(p_3-p_1)}{L}$ would instead see plane which cuts the top of the set ϕ.

The above diagram displays both the plane of marginal consumers and the plane on which atients are located. The line in the centre of the darker (marginal consumer) plane shows the ıtersection between the planes. This line is used in the following diagram to display the references of patients over drugs 1 and 3.

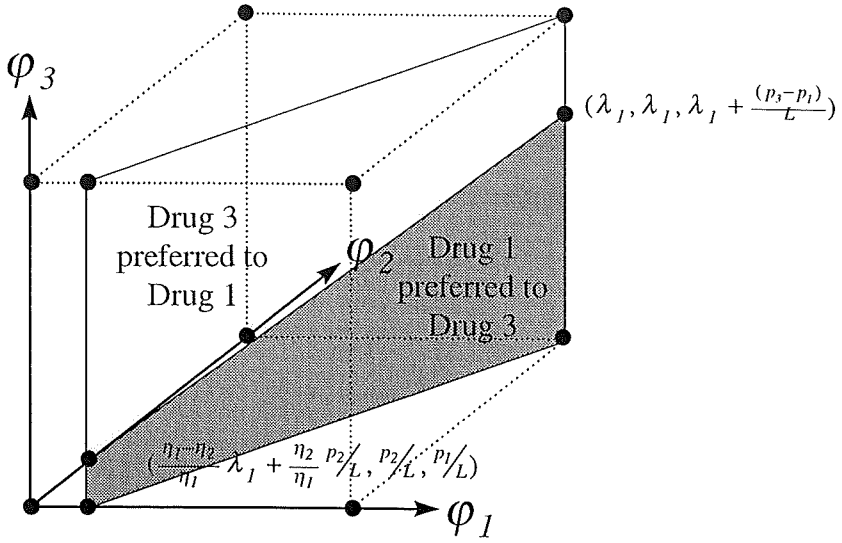


Figure 8.9: Preference relationship (drug 1 - drug 3)

The diagram showing the preferences between drugs 2 and 3 is found in much the same way as above but can be compressed onto a single figure because of the angle the planes intersect at. The darker plane below represents all points where patients are indifferent between drugs 2 and 3. The lighter plane again is the plane along which all consumers must fall. The darker line here is the line of marginal consumers that will be used in the next diagram.[19]

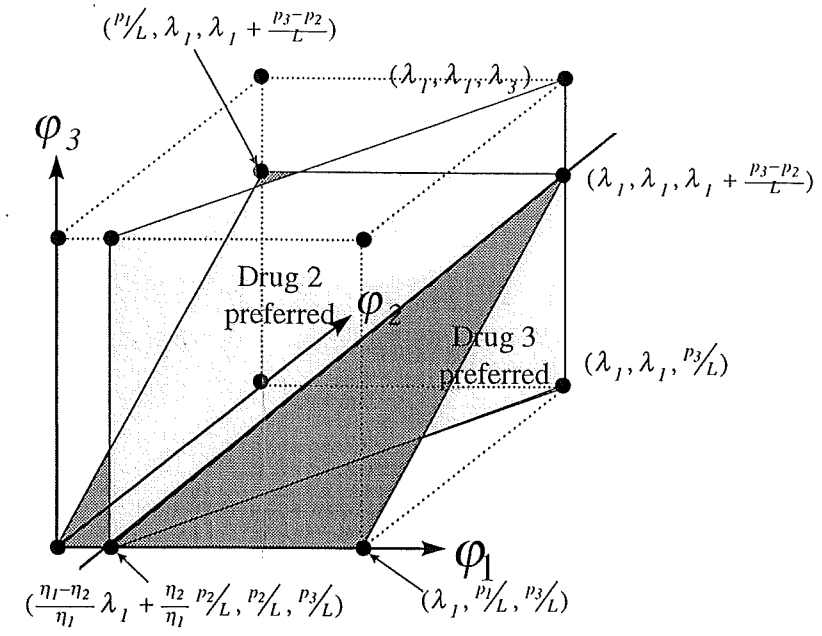


Figure 8.10: Preference relationship (drug 2 - drug 3)

---

[19] Note that $\lambda_3 - \lambda_1 > \frac{(p_3-p_2)}{L}$ has been assumed here. Were this not the case the marginal line of consumers would cut the top edge of the set ϕ.

The previous figures have allowed the a pairwise derivation of where the marginal patients tween drugs lie. The following diagram takes the three lines found above and plots them along th the plane along which the consumers lie in order to display the preferences of all patients.

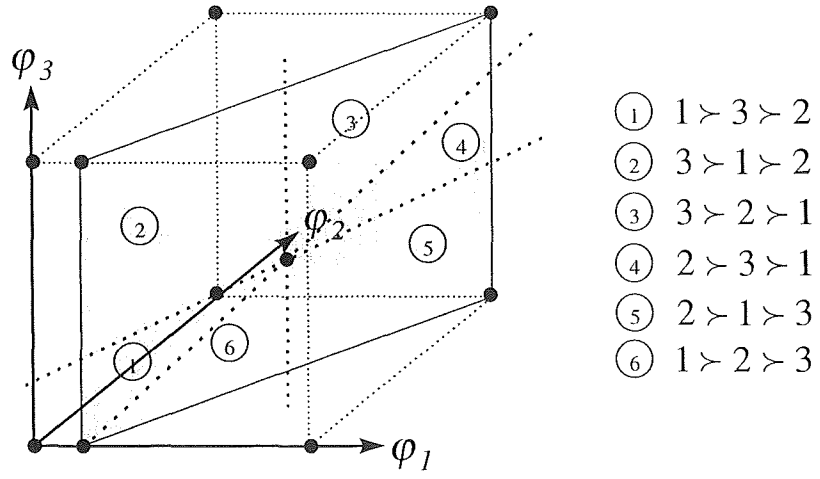


Figure 8.11: Preference areas in the location plane

The above figure allows the final choice of patients to be found; all consumers must lie on ıe plane pictured in Figure 8.6. Figure 8.7 tells us that treatment choice is a decision between :ugs 1 and 3 for patients facing $\varphi_1 < \lambda_1 - \frac{p_1-p_2}{L}\frac{\eta_1-\eta_2}{\eta_1}$ and a choice between drugs 2 and 3 for ıtients facing $\varphi_1 < \lambda_1 - \frac{p_1-p_2}{L}\frac{\eta_1-\eta_2}{\eta_1}$. Figure 8.9 and deal with each of these cases in turn and roduce a line of marginal consumers that increases in φ_1 along the plane where consumers are ɔcated. The final preferences of patients over treatment and by location is given in Figure 8.12.

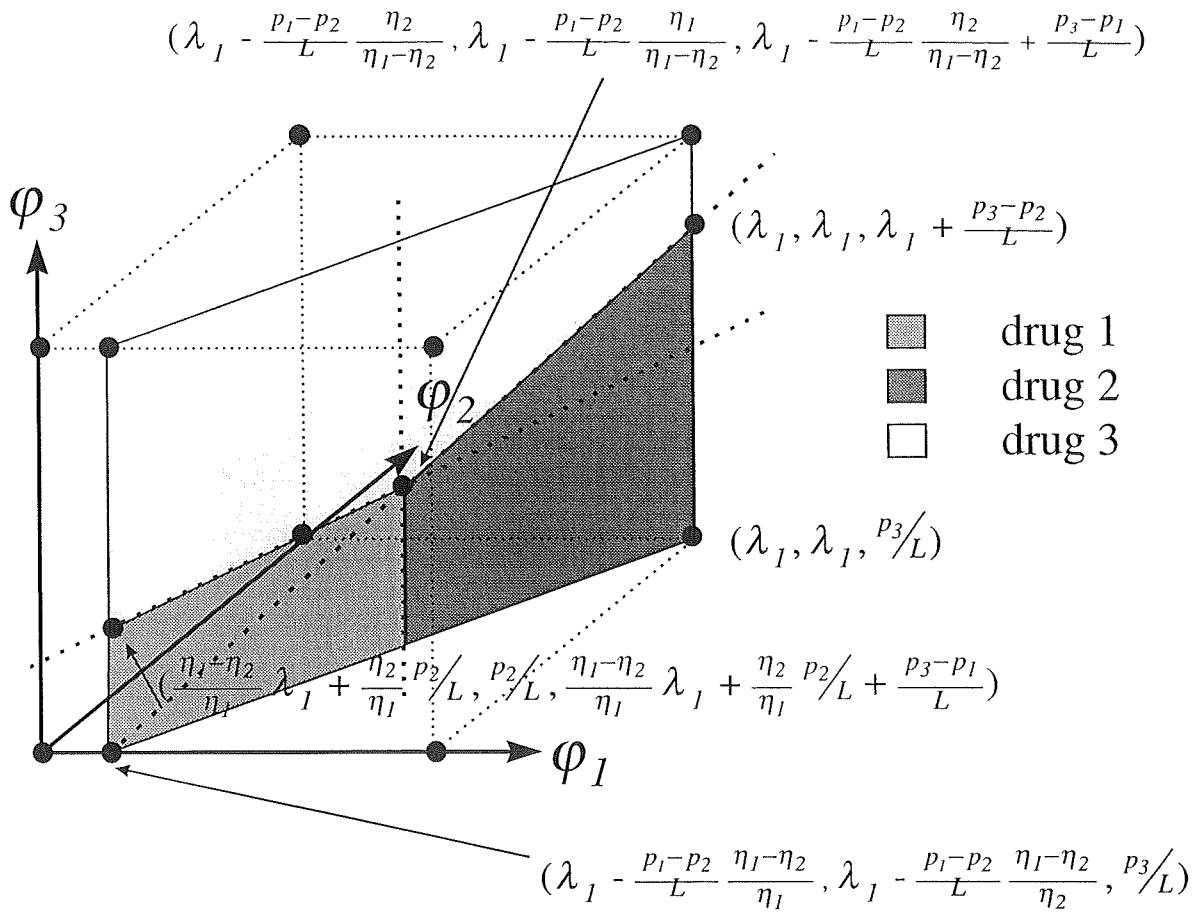


Figure 8.12: Treatment choice with a generic drug

This diagram is relatively complex but gives some intuitive results.[20] Where all drugs would be taken were they the only treatment option[21] only the best drug available is chosen. Drug 2 is assumed to be a generic copy of drug 1 and charges a cheaper price. This cheaper price means that drug 2 is preferred to drug 1 by those patients not suffering a large adverse effect from switching drugs. Where the qualities of drugs 1 and 2 are good but drug 3 is better (upper right hand of patient plane) drug 3 is selected.

Where the quality of drugs 1 and 2 are good and drug 3 is reasonable (lower right hand of patient plane) drug 2 is chosen. Here the side effects under both drug 1 and drug 2 are small and so it is not worth paying extra for drug 1.

---

[20] For the purpose of these stylised results 'good' will be taken to mean drugs close to the relevant λ_i. 'Reasonable' will be taken to mean drugs close to (but above) the relevant $\frac{p_i}{L}$.

[21] That is, $\varphi = (\varphi_1, \varphi_2, \varphi_3) \in \phi$.

By assumption drug 3 is generally better than both drug 1 and drug 2 (since $\lambda_3 - \lambda_1 > \frac{(p_3 - p_1)}{L}$ ıd $\lambda_3 - \lambda_1 > \frac{(p_3 - p_2)}{L}$). Where the quality of drugs 1, 2 and 3 are close to their respective λ values ·ug 3 is generally chosen. Where the qualities of drugs 2 and 3 are only a small distance above e relevant $\frac{p_i}{L}$ value drug 1 is typically chosen. Here drug 2 is reasonably marginal so that drug has a large side effect corresponding to it here. Because of the relationship between drugs 1 ıd 2 where drug 2 has a reasonably marginal worth drug 1 is still of a good quality. When drugs and 3 are reasonably marginal drug 1 is typically good and so is chosen.

For patients outside the set ϕ the optimal treatment choice will be as follows.[22] For patients ıcing $\varphi_1 \leq \frac{p_1}{L}$, $\varphi_2 \leq \frac{p_2}{L}$ and $\varphi_3 \leq \frac{p_3}{L}$: no worthwhile treatment options are available. For patients ıcing $\varphi_1 \leq \frac{p_1}{L}$, $\varphi_2 \leq \frac{p_2}{L}$ and $\varphi_3 > \frac{p_3}{L}$: drug 3 is chosen since it is the only worthwhile treatment ption. For patients facing $\varphi_1 > \frac{p_1}{L}$, $\varphi_2 \leq \frac{p_2}{L}$ and $\varphi_3 \leq \frac{p_3}{L}$: drug 1 is chosen since it is the only ·orthwhile treatment option. For patients facing $\varphi_1 > \frac{p_1}{L}$, $\varphi_2 > \frac{p_2}{L}$ and $\varphi_3 \leq \frac{p_3}{L}$: drug 3 is not a ·orthwhile treatment. Using Figure 8.7 drug 1 is chosen since it is better choice for low quality alues. For patients facing $\varphi_1 > \frac{p_1}{L}$, $\varphi_2 \leq \frac{p_2}{L}$ and $\varphi_3 > \frac{p_3}{L}$: drug 1 is chosen where $\varphi_1 > \varphi_3 + \frac{(p_1 - p_3)}{L}$ ıd drug 3 where $\varphi_1 \leq \varphi_3 + \frac{(p_1 - p_3)}{L}$.

Although by no means trivial Figure 8.12 does not accurately portray the difficulty of mulating the choices made by each party since it relies on a series of assumptions over the ·lative values of consumer prices for each firm.[23] With different assumptions the above iagram will look quite different with respect to its intercepts with the edge of the set $= \{\varphi_i > \text{⁄}_L, \forall i = 1,2,3\}$.

In the early part of this thesis Mathematica was used to estimate the basic pharmaceutical ıarket model. The complexity of the problem precluded the initial aim of finding a closed-form lgebraic solution for price since Mathematica required multiple 'If' statements in order to

---

[22] Since $\varphi_1 > \varphi_2$ for all patients cases where $\varphi_2 > \frac{p_2}{L}$ and $\varphi_1 \leq \frac{p_1}{L}$ are impossible and hence ignored ı the analysis.

[23] These assumptions have been placed in footnotes at appropriate points.

/aluate even simple integrals including the cumulative density function.[24] This was a result of ılls to the cumulative density function outside its normal range (above λ). As a result of this :oblem Microsoft Excel has been used for the majority of the thesis since it deals faster with the :oblem of 'If' statements in calculation and the presentation of results.[25]

To solve problems in Microsoft Excel requires the use of the 'Goal Seek' function which)lves the first order conditions of each firm numerically. The problem faced here in calculating particularly complex case for three firms is that there is no guarantee of finding convergence 'ithin an acceptable time-frame since three variables must be solved.[26] The piecewise nature of valuating quantity in the above makes it too difficult to use Mathematica where first order)nditions could ordinarily be solved algebraically.

While a difference in risk between the patented and generic drugs is a more realistic :amework to evaluate the effects of patent expiration than a difference in efficacy it is not :asible to use it.[27] The difference in efficacy framework will be used from this point when :ferring to generics in a framework with at least two independent drugs.

V. EFFECTIVE PATENT LIFE

The effective patent life of a drug is defined as the residual time available for a firm to :coup development costs without threat of generic entry after product development, the atisfaction of regulatory requirements and finally registration of the drug. It has been estimated

---

[24] Mathematica does not differentiate any function including an 'If' statement, causing a serious)roblem in computation.

[25] Except in the case of finding consumer surplus approximations where, due to the algebraic :omplexity of the required integral and a lack of 'If' statements, Mathematica is used.

[26] A three variable case should present few problems in the cases where either three independent or hree totally correlated distributions are concerned. It is the mixture of totally correlated and non :orrelated distributions that cause problems here.

[27] The difference in risk framework would allow for both firms to survive in the long term after)atent entry.

at under New Zealand's existing patent system effective patent life will fall to only 5.98 years the year 2000 and that this figure will decrease further over time.[28]

New Zealand, as a small nation, faces the temptation to allow this erosion of patent otection. The smaller is patent life the sooner New Zealand has access to cheaper generic ugs which reduces subsidy costs in New Zealand. Two schools of thought exist on the nportance of effective patent life to small nations.

Johnston and Zeckhauser represent the first of these factions. They suggest that one of the vourable points behind the scheme the Australian government implemented in the 1980's was at it allowed for the reduction of profits to the pharmaceutical industry. This obviously rresponds to a fall in subsidy costs and an increase in consumer surplus. Geographic obscurity nd the relatively small size of the Australian market (on a global scale) was thought to allow ustralia to implement this scheme without attracting significant interest from the global harmaceutical industry. Australia, it was suggested, was able to free ride on drug research by sing the scheme outlined in Chapter 7.

Such a scheme begs that a few questions be answered. Would the pharmaceutical industry ctually be unaware of the nature of the Australian scheme and if so would they react? It would ppear that pharmaceutical firms must take attempts to free ride on research seriously. By gnoring the actions of the Australian government the pharmaceutical industry runs a serious risk f appearing weak to other small nations who would look to free ride on drug research in much ne same way. Although the actions of one small nation are unlikely to significantly alter the rofits of any multinational drug company it is unlikely that this will hold for actions of several r all such nations. The lost profits firms accept by not entering nations who seek to free ride on rug research may be outweighed by the risk of appearing weak to other small nations eager to educe their drug bill. Remaining ignorant of the structures countries have in place does not ppear to be optimal for pharmaceutical companies.

The other major question a desire to free ride raises regards time inconsistency. All nations lesire advances in pharmaceuticals but these developments are costly. If nations decide now not

---

[28] Parker, J. (1997) Pharmaceutical Patent Reform in New Zealand. *New Zealand Economic Papers* 31(1):85-91.

fund the pharmaceutical industry for the research and development that has gone into their ·oducts then further research becomes unlikely.

John Parker[29] takes the alternative view that, although tempting, a nation is better to accept ıt it must contribute to the research and development costs of the pharmaceutical industry. ıiling to do so, he argues, would have a myriad of negative effects. The pharmaceutical ıdustry is unlikely to invest in countries where it perceives that it will be treated badly which ıay account for some of drop in investment in New Zealand by drug companies.

Firms may delay the introduction of drugs and/or demand higher prices in order to ɔnvince other nations that attempts to free ride will not be tolerated.[30] This would quickly ːduce the quality of available treatments in free-riding countries compared to those that do not ıd serve as a powerful deterrent since patients will demand that governments make sure such eatments are available.

Trade sanctions are also possible if the government is perceived not to allow an acceptable ːvel of protection for intellectual property. New Zealand was threatened with such sanctions in 991 in order to force modification of the *Patents Act 1953*.[31] Parker argues that there are efinite risks in not allowing for significant protection of the pharmaceutical industry through the atent system. The relatively low effective patent life in New Zealand would suggest that the ·uth of these claims may soon be known.

If the government finds that contributing to research and development is a prerequisite for a ɛsponsible pharmaceutical system the results of the previous chapter would surely change. 'hese results of Chapter 7 were generated under the JZ scheme which accepts and supports free ıding. Giving additional funds to firms or using option one of the Johnston and Zeckhauser ɛport would achieve the aim of giving a credible commitment to intellectual property in the area

---

[29] Parker, J. (1991) *Pharmaceutical Patents in New Zealand.* Auckland, NZ, IMS(NZ) Ltd. 161p.

[30] Here Parker refers to the 1992 Ministry of Commerce publication *Reform of the Patent Act 953: proposed recommendations.*

[31] The US Omnibus Trade and Competitiveness Act allows the United States to place sanctions on ountries who are judged not to provide adequate protection for intellectual property. In 1991 New 'ealand was placed on the watch list and the following year pressure from the United States Trade ɛepresentative led to a repeal of a section of the Patents Act 1953. (see Baker, A. Pharmaceuticals fight ıot the first New Zealand has faced. *National Business Review.* 24 April 1997. p.20)

fund the pharmaceutical industry for the research and development that has gone into their ɔducts then further research becomes unlikely.

John Parker[29] takes the alternative view that, although tempting, a nation is better to accept ıt it must contribute to the research and development costs of the pharmaceutical industry. iling to do so, he argues, would have a myriad of negative effects. The pharmaceutical ılustry is unlikely to invest in countries where it perceives that it will be treated badly which ıy account for some of drop in investment in New Zealand by drug companies.

Firms may delay the introduction of drugs and/or demand higher prices in order to nvince other nations that attempts to free ride will not be tolerated.[30] This would quickly ıuce the quality of available treatments in free-riding countries compared to those that do not d serve as a powerful deterrent since patients will demand that governments make sure such :atments are available.

Trade sanctions are also possible if the government is perceived not to allow an acceptable vel of protection for intellectual property. New Zealand was threatened with such sanctions in)91 in order to force modification of the *Patents Act 1953*.[31] Parker argues that there are :finite risks in not allowing for significant protection of the pharmaceutical industry through the ıtent system. The relatively low effective patent life in New Zealand would suggest that the ıth of these claims may soon be known.

If the government finds that contributing to research and development is a prerequisite for a sponsible pharmaceutical system the results of the previous chapter would surely change. ıese results of Chapter 7 were generated under the JZ scheme which accepts and supports free ding. Giving additional funds to firms or using option one of the Johnston and Zeckhauser port would achieve the aim of giving a credible commitment to intellectual property in the area

---

[29] Parker, J. (1991) *Pharmaceutical Patents in New Zealand.* Auckland, NZ, IMS(NZ) Ltd. 161p.

[30] Here Parker refers to the 1992 Ministry of Commerce publication *Reform of the Patent Act)53: proposed recommendations.*

[31] The US Omnibus Trade and Competitiveness Act allows the United States to place sanctions on ɔuntries who are judged not to provide adequate protection for intellectual property. In 1991 New :aland was placed on the watch list and the following year pressure from the United States Trade epresentative led to a repeal of a section of the Patents Act 1953. (see Baker, A. Pharmaceuticals fight ɔt the first New Zealand has faced. *National Business Review*. 24 April 1997. p.20)

f pharmaceuticals. Note that such a JZ scheme giving full duopoly profits to firms would still e superior to the unrestricted form of reference pricing addressed in Chapter 6 which gave far reater profits to pharmaceutical companies than would have been received in the absence of ubsidisation.

CHAPTER 9

DELAYS IN BARGAINING

Bargaining games are defined as situations where two or more parties must agree on the llocation of a set gain from trade. In an economic context the gain from trade is typically the ifference between the valuations of the buyer and seller of an item of value. For the xchange of ownership to occur both parties must agree on the price the seller receives. Both ıe type of model used and the knowledge each party brings into negotiations is of vital onsequence in predicting how long negotiations will last.

DELAYS IN COOPERATIVE GAME THEORY

Cooperative models of bargaining place the buyer and seller at a negotiating table and ttempt to predict the outcome of bargaining by restricting possible solutions to those atisfying conditions deemed desirable. The actual bargaining procedure is not defined but is xpected to promote outcomes satisfying these pre-defined axioms. Nash[1] defined four xioms a solution should exhibit:

(i) Affine transformations of utility shall not alter the expected outcomes (*invariance to quivalent utility representations*).

(ii) If both players are identical in every respect each player shall receive the same ıtility at the expected outcomes (*symmetry*).

(iii) Allocations may be discarded from the game so long as the solution to the original ;ame is not removed and the reduced game shall retain the same solution as the original *independence of irrelevant alternatives*).

(iv) Players shall never agree on a Pareto inefficient outcome.

Osborne and Rubinstein analyse this final axiom and reach the following conclusion:

> "If we reinterpret each [possible agreement] as a pair consisting of a physical agreement and the time at which this agreement is reached, and we assume that

[1] Nash, J.(1953) Two-Person Cooperative Games. *Econometrica* 21:128-140.

resources are consumed by the bargaining process, then [the Pareto optimality axiom] implies that agreement is reached instantly."[2]

The four axioms define a unique outcome termed the Nash Bargaining Solution. This outcome is achieved immediately and relies on either the foreknowledge or full and accurate disclosure of all relevant information. Where pertinent information is not known by all parties cooperative bargaining theory is not applicable as it does not address the incentives firms have to misrepresent their position. By contrast, non-cooperative theory accounts for this incentive when predicting the outcome of the bargaining process.

I. DELAYS IN NON-COOPERATIVE GAME THEORY

Non-cooperative game theory imposes several standard restrictions on the preferences and positions of each player.

(i) Disagreement (or alternatively a breakdown in bargaining) is assumed to be the worst possible outcome for every player.

(ii) Utility is generally assumed to increase in the share of 'pie' received.

(iii) Utility is assumed to decrease in the time to agreement, generally as a result of discounting or the imposition of a constant delay cost.[3]

(iv) that if the same utility is offered to a player both today and in a future period the player will take the utility today

Finite non-cooperative games fall in two distinct categories:[4] those in which all pertinent information is known by all parties (complete information) and those in which some

---

[2] Osborne, M. and Rubinstein, A. (1990) *Bargaining and Markets*. San Diego, CA., Academic Press, Inc. p 11-13. The analysis by Osborne and Rubinstein may be suspect in that it analyses the prospects for delay within the entirely static framework of Nash's model. If, for example, the disagreement point changes over time there appears to be room for some delay. Here backwards induction may however still provide a solution without delay but it is unlikely to be the Nash bargaining solution for the static game taken at time zero.

[3] Normally discounting is preferred since it provides more interesting results. Bargaining with constant costs to delay may promote an outcome of attrition where each party waits until it can ascertain that it has a greater cost to delay than its opposition. Once such a conclusion has been reached the player in question will relinquish any remaining surplus to their opposition.

[4] Only models with a finite time period are considered since patents provide only limited protection against generics. The assumptions made in the previous chapter imply that on generic entry the firm

formation is private (incomplete information). The likelihood and meaning of delay in the ontext of each of these games differ.

(1) Non-cooperative games of complete information

In non-cooperative games of complete information a single subgame perfect equilibrium xists in which agreement is reached without delay.[5] Backwards induction allows the parties) ascertain this equilibrium in the first period, promoting an efficient outcome in the sense iat agreement is reached without delay.

A simple example of such a game follows: suppose two players are involved in a three eriod game where Player 1 proposes an initial division of $1 between the players. Player 2 iay either accept this allocation or counter with a second allocation. If Player 2 opts for the itter time elapses, decreasing the size of the available surplus. If play reaches the second eriod Player 1 must decide whether or not to accept Player 2's offer or make a final take-it-r-leave-it offer with a further reduced pie.

The application of backwards induction to this game presents an obvious solution. Let δ)e a discount factor common to both parties. Suppose further that the game reaches the final)eriod so that δ^2 is available. As long as Player 1 offers Player 2 some $\varepsilon > 0$ she knows that 'layer 2 will accept. The expected payoff to Player 1 of rejecting an offer in the second)eriod is then approximately δ^2.

In the second period Player 2 must offer Player 1 at least δ^2 for the offer to be accepted. The maximum surplus available to Player 2 is then $\delta - \delta^2$. In the first period $1 is available for livision between the players. Player 1, for the offer to be acceptable, must give $\delta - \delta^2$ to 'layer 2. The maximum amount Player 1 may take for herself is then $1 - \delta + \delta^2$. The :quilibrium strategies for both players are given below.

---

s effectively removed from the market by the process of Bertrand competition. The firm faces a imited time horizon in decision making and so only finite games are applicable..

[5] Under alternating offers. Note that other equilibria will typically exist but are not subgame)erfect. As these alternative outcomes are not based on credible threats by all parties they are gnored.

Where payoffs are denoted (x, y):

	Player 1	Player 2
1st period	Offer $(1 - \delta + \delta^2, \delta - \delta^2)$	Accept all offers with $y \geq \delta - \delta^2$
2nd period	Accept all offers with $x \geq \delta^2$	Offer $(\delta^2, \delta - \delta^2)$
3rd period	Offer $(\delta^2, 0)$	Accept all offers with $y \geq 0$

Table 9.1: Equilibrium strategies in the complete information game.

In equilibrium agreement occurs in the first period with the allocation $(1 - \delta + \delta^2, \delta - \delta^2)$.

Backwards induction allows each player to extrapolate into future periods and examine ıe equilibrium actions they, and others, would take if the opportunity arises. Each player ıakes current decisions based, in part, on their knowledge of the payoff the other player faces ı each circumstance. In games of incomplete information there is no guarantee that each layer will know the payoffs of the other players and cannot always ascertain the choices ıade by the other players in the future. Backwards induction thus loses its power when ertinent information is not available to all players.

In complete information games delay is a definite source of inefficiency because it ecreases the available gains from trade. Delay here serves no worthwhile purpose because ll information is known in each period of time and so attempts at deception or opportunism vill inevitably be both unsuccessful and wasteful.

(2) Non-cooperative games of incomplete information.

As mentioned above the process of backwards induction does not give satisfactory ıredictions where the information players hold about other players is incomplete. It has been ırgued that in this type of game delay takes on a meaning above that of simply a potential ource of inefficiency. Kennan and Wilson (KW) argue that:[6]

> An alternative hypothesis, however, is that delays and failures to agree are inefficient *ex post* only from the privileged view of hindsight. The substance of this hypothesis is that bargaining is substantially a process of communication necessitated by initial differences in the information known to the parties. Thus, delay may be required to

[6] Kennan, J. and Wilson, R. (1993) Bargaining with private information. *Journal of Economic Literature* 31(1):45-104.

convey private information credibly. For instance, willingness to endure a strike might be the only convincing evidence that the firm is unable to pay a high wage.

A buyer can always assert that the value he places on an item is low in order to pay a naller amount for it. Regardless of their true value every buyer has this incentive and so ccordingly claims the lowest possible value. The seller will take none of these claims redibly unless the buyer can reliably show their true valuation. Since cheap assertions of ieir value are not convincing proof more concrete action is required. Two alternative models f information revelation have been suggested; screening (price discriminatory) models and ignalling.[7] It must be noted that the "screening" and "signalling" labels have been used to escribe different models by various authors. Since much of this discussion is inspired by KW their definitions are used here. These definitions focus on the procedures motivating ach type of equilibrium. KW define screening equilibria as equilibria that arise where:[8]

> one or both parties make offers at prescribed intervals, so that rejection of an offer entails an appreciable cost of delay until another offer can be made. The [seller's] price discrimination exploits this feature by, in effect, including with each offer to the firm the admonition to remember that rejecting the offer entails a costly wait before a better offer will be forthcoming

Signalling equilibria are also defined in the same way:[9]

> Signalling equilibria arise when either party can delay arbitrarily long before responding to an offer, thus enabling the length of the delay to act as a signal.

The distinction between screening and signalling models arises through the differing tructures each model has with respect to time and delay. In a signalling model delays are letermined endogenously with each party waiting before responding to an offer and using this ength of delay as a credible signal to their true value. Signalling models treat time as a continuous variable, and so use continuous discounting. In a screening model the delay period s typically denominated in fixed units with at least one party making offers at the endpoints of each period. Standard screening models approach discounting with the use of discrete liscount factor.

---

[7] A third 'type' of model proposed by Kennan and Wilson, where each player has an additive linear cost of delay, falls into the same general category of signalling since bargaining continues until it has been signalled that a player's own cost of delay has been signalled to fall above that of their competitor(s).

[8] Kennan, J. and Wilson, R. (1993) p 56.

[9] Kennan, J. and Wilson, R. (1993) p 56.

(a) Screening

A screening equilibrium involves a situation where the non-informed party (seller) ffers a sequence of decreasing prices over time. It is generally assumed that the seller cannot eliably commit to a sequence of prices so that the price offered in each period is a result of an ptimisation in that period. High value buyers are more impatient to receive the good than ower value buyers and so are willing to pay a higher price for it. The buyer chooses the first rice that gives it a positive utility greater than that expected were it to wait for the next eriod. The actions of the non-informed party allow the buyers to reveal their type by their ctions.

The original research on screening equilibria did not focus on a bargaining model but nstead as a theory to explain durable goods pricing. In her 1982 paper Nancy Stokey xplored the problem of how a monopolist would release quantity to the market over time. By sing a continuous time frame she showed that the only perfect rational expectations quilibrium involves releasing the full market quantity at price equal marginal cost in the first eriod. Such a perfect rational expectations equilibrium has the following properties:[10]

A perfect rational expectations equilibrium has the following properties:

- Each contingent sales strategy maximises the present discounted value of profits, given the relevant initial condition for the stock and given buyers' expectation functions, and
- given any initial level of the stock at any date, buyer's expectations are fulfilled along the realised path of production from that date on.

In the more interesting case of positive period lengths she showed that equilibria exist with positive quantity releases in each period until the market is saturated. The model was further analysed by Sanford Grossman and Motty Perry (1986)[11], Joel Sobel and Ichiro Takahasi (1983)[12] and Faruk Gül, Hugo Sonnenschein and Robert Wilson (1986)[13]. These

---

[10] Stokey, N. (1981) Rational Expectations and Durable Goods Pricing. *Bell Journal of Economics* 12(1):112-128.

[11] Grossman, S. and Perry, M. (1986) Sequential Bargaining under Asymmetric Information. *Journal of Economic Theory* 39(1) pp. 120-154.

[12] Sobel, J. and Takahashi, I. (1983) A Multistage Model of Bargaining. *Review of Economic Studies* 50(3):411-426.

[13] Gul, F. and others. (1986) Foundations of Dynamic Monopoly and the Coase Conjecture. *Journal of Economic Theory* 39(1):155-190.

apers analysed the validity of the Coase conjecture. This conjecture addressed the price of ejecting an offer from a durable goods monopolist, asserting that consumers would accept nly the lowest valuation and wait until this valuation was realised before purchasing nything. The monopolist would choose to saturate the market in equilibrium rather than elease their product gradually.

KW use the following model as a example of the screening equilibrium concept. Delay osts are incorporated into a model of wage negotiation. The firm is placed in the position of nowing the gain from trade, v, which is the benefit to the firm of employing union labour bove the market wage rate. The union does not know the gain from trade but accurately onjectures that it is uniformly distributed on [0, 1].

If the parties agree on a premium p, the union receives a payoff of δ^n where the nth offer s accepted. Given such a settlement the firm receives $[v\text{-}p]\delta^n$ in profits. This game has a imple but non-unique equilibrium[14] where the firm accepts the first offer that is not more han βv, and the union offers a premium $p = \alpha\bar{v}$ where history denotes that the buyer's 'aluation is at most $\bar{v}$.

Initially $\bar{v}=1$ and the first offer the union makes is $p = \alpha$ which is accepted by all firms vith valuations above α/β. Since $\bar{v}=\alpha/\beta$, the offer made is $p=\alpha^2/\beta$ which is accepted by emaining firms with a valuation above α^2/β^2. The nth offer is $p=\alpha^n/\beta^{n-1}$ which is accepted by ll firms with valuations between $(\alpha/\beta)^n$ and $(\alpha/\beta)^{n-1}$. The derivation of the parameters α and β s omitted but it can be shown that $\alpha=\frac{\sqrt{1-\delta}}{1+\sqrt{1-\delta}}$ and $\beta=\sqrt{1-\delta}$. It is interesting to observe the predicted behaviour as the discount period falls:

(i) (Trivially) the discount rate approaches 1.
(ii) Both α and β tend towards zero. For small period lengths the union offers only a small portion of $\bar{v}$ with very firms accepting the offer since both parameters are small.
(iii) The average number of periods to an agreement increases.
(iv) The expected time to agreement falls to zero (the average number of periods increases more slowly than period length).
(v) The offer accepted falls to zero.

---

[14] Non-uniqueness is a common problem in these models. Non-uniqueness is often be lleviated by the use of specific refinements such as stationarity.

The final point is the crux of the Coase conjecture. If offers are made continuously the nion cannot credibly demand a premium on its labour. The firm, on perception of an offer ɔove zero will (costlessly) wait until the next period in order to obtain a lower premium. ince the union attracts no firms when offering a positive premium it will not do so. If the 'oase conjecture is applicable in the pharmaceutical market model it carries with it an nportant implication. Here, if the agency is not able to impose a positive delay length, in any erfect equilibrium consistent with rational expectations the drug agency will pay an amount ıfficient to compensate the highest possible cost provider of the pharmaceutical immediately nd no delay will eventuate.

(b) Signalling

The second concept addressed here to model information revelation is signalling. The oncept of a signalling equilibrium reverses the roles of each party from those observed in a creening equilibrium as far as information revelation is concerned. Signalling equilibria llow the informed party to credibly signal the non-informed party by the use of delay. Using he firm/union framework above: after an offer by the union the firm may decide how long to lelay before accepting the offer or making a counter-offer. The length of delay selected eveals the type of the firm and is represented by the delay function $t(v)$. In an equilibrium this ignal must be credible and accurate and so the union infers that, given a signal of t, the value nust be no more than $v(t)$, the inverse of $t(v)$.

The Nash bargaining solution (NBS) of a game where both parties have the same lisagreement payoff sees the surplus shared equally between the parties. This result is used to ɔredict the outcome of negotiations between the firm and the union once the value of the ınion labour is revealed. Here half the value of the union labour above the market wage ıccrues to each party. Where the interest rate[15] is r the firm faces the utility function:

$$U(v,r) = \max_{t} \left[v - \tfrac{1}{2}v(t)\right]e^{-rt}.$$

[15] For discounting purposes.

In an equilibrium the optimal choice of t must be $t(v)$. Suppose now that the value of v ılls in the range $[0, a]$. The optimality of t allows $v(t)$ to be derived in the following way:

$$U(v,r) = \max_t \left[v - \tfrac{1}{2}v(t)\right]e^{-rt}$$

$$0 = -rve^{-rt} + \tfrac{1}{2}rv(t)e^{-rt} - \tfrac{1}{2}\tfrac{dv}{dt}e^{-rt}$$

$$0 = -\tfrac{1}{2}rv(t)e^{-rt} - \tfrac{1}{2}\tfrac{dv}{dt}e^{-rt}$$

$$0 = rv(t) + \tfrac{dv}{dt}$$

$$v(t) = Ae^{-rt}$$

nd at t=0, $v(0) = A$ so that $v(t) = v(0)e^{-rt}$.

The value $v(0)$ corresponds to the maximum available gain since this firm can not gain ›y signalling at a positive time in equilibrium.[16] This restriction allows the final form of the mplied value function to be found so that $v(t) = ae^{-rt}$.[17]

This example shows the general steps required to find a signalling equilibrium. Under a ignalling equilibrium a perfect information solution concept is adopted with payoffs ıttributed to each party according to this solution. In the example above this solution was the NBS where each party had the same disagreement payoff. The signalling equilibrium allows he informed party to wait for a sufficient period of time to allow them to signal their true ype.

A payoff function is defined with the aid of the solution concept. In the above case the ›ayoff to a firm with costs v in the perfect information case is $\frac{1}{2}v$. If a firm signals at time t it s instantly assumed that this firm is of type $v(t)$ and so receives $\frac{1}{2}v(t)$, the payoff a firm with ype $v(t)$ would receive in the perfect information case. The firm, as the informed party, ›bserves $v(t)$ and decides when it will signal. This choice is represented by the expansion of he first order condition of the firm's utility function above.

Now for the union to wish to retain the same offer function $v(t)$ the signals given by the ïirms must be credible. A firm with value v must find it optimal to signal at time t^* where

---

[16] Since a firm with a marginal cost of zero must signal first. If this firm signals after a delay :hen all firms must wait to credibly signal costs which decreases payoffs to all possible firms without ›enefiting any individual firm. In equilibrium a firm with a marginal cost of zero signals at time zero in order to prevent wasteful delay.

[17] $v(t) = ae^{-rt}$, $\ln v = \ln a - rt \ln e$, so $t(v) = \ln \frac{a}{v}/r$.

$(t^*) = v$. This restriction is imposed on the first order condition of the firm. The resulting ifferential equation is solved and an appropriate boundary condition applied to define the inction $v(t)$. This function is optimal in all cases where the perfect information solution is ie NBS and all firms have identical disagreement positions.

A sequence of steps very close to those given above is performed in Section IV when ie signalling framework is modified for use in the pharmaceutical market.

II. SCREENING IN THE PHARMACEUTICAL MARKET

The proposed model of Johnston and Zeckhauser is based on a single period, complete nformation setting. The move to a multi-period, incomplete information setting allows a ignificant degree of freedom in the creation of the model used. The information each party ias at their disposal, bargaining rules and the possible cost structure of firms must be defined iefore any analysis of screening equilibria in the pharmaceutical market is possible.

Both the pharmaceutical agency and drug companies are assumed to have complete nformation over the characteristics of all relevant pharmaceuticals in the marketplace. While he pharmaceutical companies will know the marginal cost of their product there is :onsiderable doubt as to whether the subsidising agency will. It is assumed that the marginal :ost of a drug is distributed uniformly along an interval bounded below by zero. A marginal :ost of 2 has been assumed for the upper bound of this interval. Both the agency and firms are issumed to share a common discount factor $\delta = e^{-r\Delta}$ where r is the interest rate and Δ is the ieriod length.

A screening equilibrium in the pharmaceutical market model will be characterised by he agency making a series of subsidy offers of the form: at time t the agency suggests a iroducer price p_t in exchange for an agreement to price at a consumer price p_t^c. A subsidy of $(p_t - p_t^c)$ is provided by the agency on $\mu(p_t^c)$ units of the drug, which is the amount purchased iy patients at the relevant consumer price. The drug companies must decide if and when to iccept subsidisation on these terms. If the company declines the offer of subsidisation it must wait until the next period to observe the new offer. In this time profit will still occur for the

on-subsidised drug. Here the price charged by the producer is $\bar{p}$ which attracts custom of $\bar{\mu}$. hese prices are known by the agency since they are observed pre-subsidisation.

Generics are expected to enter the market after time T when the patent expires.[18] It is xpected that the generic and innovative firms will engage in undercutting until the generic revails.[19]

A generic firm has to compete firm with marginal cost c accepting subsidisation at time accepts a price p_t in return for charging at p_t^c. The simplest version of this model sees p_{t+1}^c onstant over t. Setting p_{t+1}^c equal to 0 firms face profits of[20]

$$\frac{1-\delta^{T+\tau-t}}{1-\delta}(p_t - c)\mu(0).$$

If the firm was to instead reject the offer and accept the next period's offer it receives

$$(\bar{p} - c)\bar{\mu} + \frac{\delta - \delta^{T+\tau-t}}{1-\delta}(p_{t+1} - c)\mu(0).$$

This term is not the profit accruing to a firm that rejects p_t but rather the profit accruing o a firm who accepts p_{t+1} in the following period. Firms close to the marginal firm are xpected to accept subsidisation in the following period if they do not do so the current one.

For these firms the expression above is equal to the profits they gain if they choose to eject the current offer. For the marginal firm these profits are equal. Solving the above xpressions for the marginal firm's costs, c^*, the following can be derived.

$$c^* = \frac{p_t\mu(0) - \overline{p\mu}}{\mu(0) - \bar{\mu}} - \frac{\mu(0)}{\mu(0) - \bar{\mu}} \frac{\delta - \delta^{T-t}}{1-\delta}(p_{t+1} - p_t)$$

---

[18] The section on the sensitivity of results includes a scenario with a positive delay before eneric entry.

[19] It is acknowledged that in reality the generic does not defeat the innovative firm. Chapter 8 ives the reasons for the choice of assumptions leading to this unrealistic outcome. These assumption hould not affect the validity of the results obtained in this thesis as (1) events beyond generic entry re heavily discounted by firms and (2) the JZ scheme can be engineered to allow for modification of ubsidies at the time of generic entry. Several studies has suggested that both firms remain in the narket with the generic pricing below the level previously seen and the innovator increasing its price lightly (see Frank, R. and Salkever, D. (1992) Pricing, Patent Loss and the Market for harmaceuticals. *Southern Economic Journal* 59(2):165-179).

[20] Assuming, for the moment, that fixed costs are zero. See Appendix 9.1 for derivation.

Firms that have not previously accepted subsidisation and have marginal costs below c^* ill now join. Firms with marginal costs above c^* prefer the next period's offer to the current ne and so wait until the following period.

The drug agency is assumed to place a value, V, on the subsidisation of the harmaceutical commensurate with its characteristics. A positive multiple of the increased onsumer surplus resulting from subsidisation is a relatively natural assumption for this value ince superior drugs should be more desirable for the agency, all other things being equal. ach period the agency performs the following maximisation:

$$V_n(c^*_{t-1}) = \max_{p_t}\{\ (V-p_t)(c^*_t - c^*_{t-1}) + \delta V_{n+1}(c^*_t)\ \}$$

where $c^*_0 = 0$ and $V_{T+1}(c_T) = 0$.

Because the definition of c_t^* includes a reference to the following period's price any quilibrium must be solved recursively. *Microsoft Excel* was used to set up the system of quations which were then solved, period by period, until the values of p_t converged in every eriod.[21] These estimations were not particularly fruitful however since they resulted in nultiple equilibria. This is not uncommon with screening equilibria and is often alleviated by he use of a restriction that strategies must be stationary.[22] Stationary strategies have the roperty that the prescribed actions depend on neither past experience nor the time period. While a case can be made for the former of these restrictions the latter makes very little sense ince a firm with cost c will choose to accept subsidisation if and only if[23]

$$p_t > c + (\overline{p} - c)\frac{1-\delta}{1-\delta^{T-t}}\frac{\overline{\mu}}{\mu(p_t^c)} + \frac{\delta - \delta^{T-t}}{1-\delta^{T-t}}(p_{t+1} - c)\frac{\mu(p_{t+1}^c)}{\mu(p_t^c)}.$$

The above strategy is dependant on the time period since $\mu(p_t^c)$, $\mu(p_{t+1}^c)$, p_{t+1}, and the liscounting terms all potentially change with t. Without the restriction of stationary strategies he problem of multiple equilibria appears not to have a simple solution. Adding this problem

[21] Using the *Solver* algorithm.

[22] For example Gul, F and others (1986) use stationarity to obtain a unique equilibrium in the situation where an agreement to trade is always optimal.

[23] See Appendix 9.2.

the length of time taken for convergence for even relatively small (100 period) models and e screening equilibrium concept begins to look particularly unappealing.[24]

Of more concern than this problem is the inability of the screening model to incorporate ven simple strategic behaviour into the bargaining mechanism. Since producer prices are efined endogenously the only pieces of information that the screening model takes from the Z framework is the relationship between revealed cost and consumer price. The screening quivalent of the JZ scheme with zero prices is then simply the screening problem where onsumer prices are zero. Likewise under the marginal cost framework the screening quivalent of the JZ scheme is simply the screening problem where charging the average cost f a firms who optimally choose to join the scheme in that period.

The screening mechanism only uses the definition of consumer prices from the perfect nformation version of the JZ model. Any scheme that gives the same consumer prices to the creening mechanism will have exactly the same results as the JZ model. The strategic rength of option four of the JZ scheme (in that it attempts to create a prisoner's dilemma ame) is ignored and the result obtained is exactly the same as any other option where both rms are subsidised and set zero consumer prices. Screening equilibria appear to render mpossible any strategic behaviour beyond the price discrimination of the uninformed party.

Analysis of different schemes under a screening framework becomes trivial as, unless onsumer prices differ between the alternative schemes or some restriction is placed on quilibria, all schemes promote exactly the same outcome.

V. SIGNALLING IN THE PHARMACEUTICAL MARKET

The model used here for signalling in the pharmaceutical market is very similar to the xample of a signalling model found above. Here the drug companies credibly signal their narginal costs through the use of delay.[25] As with the signalling example of Section II 2b the

---

[24] Time to convergence varied from approximately 15 minutes for models with 10 periods to atent expiration to over 15 hours for some models with 100 periods to expiration.

[25] There is a possibility that the signalled cost may in practice be marginal production cost plus n expectation of foregone profits in overseas markets due to the lowering of international price

the length of time taken for convergence for even relatively small (100 period) models and e screening equilibrium concept begins to look particularly unappealing.[24]

Of more concern than this problem is the inability of the screening model to incorporate ven simple strategic behaviour into the bargaining mechanism. Since producer prices are efined endogenously the only pieces of information that the screening model takes from the Z framework is the relationship between revealed cost and consumer price. The screening quivalent of the JZ scheme with zero prices is then simply the screening problem where onsumer prices are zero. Likewise under the marginal cost framework the screening quivalent of the JZ scheme is simply the screening problem where charging the average cost f a firms who optimally choose to join the scheme in that period.

The screening mechanism only uses the definition of consumer prices from the perfect nformation version of the JZ model. Any scheme that gives the same consumer prices to the creening mechanism will have exactly the same results as the JZ model. The strategic rength of option four of the JZ scheme (in that it attempts to create a prisoner's dilemma ame) is ignored and the result obtained is exactly the same as any other option where both rms are subsidised and set zero consumer prices. Screening equilibria appear to render mpossible any strategic behaviour beyond the price discrimination of the uninformed party.

Analysis of different schemes under a screening framework becomes trivial as, unless onsumer prices differ between the alternative schemes or some restriction is placed on quilibria, all schemes promote exactly the same outcome.

V. SIGNALLING IN THE PHARMACEUTICAL MARKET

The model used here for signalling in the pharmaceutical market is very similar to the xample of a signalling model found above. Here the drug companies credibly signal their narginal costs through the use of delay.[25] As with the signalling example of Section II 2b the

---

[24] Time to convergence varied from approximately 15 minutes for models with 10 periods to atent expiration to over 15 hours for some models with 100 periods to expiration.

[25] There is a possibility that the signalled cost may in practice be marginal production cost plus n expectation of foregone profits in overseas markets due to the lowering of international price

ıgnal the non-informed party (the subsidisation agency) receives is the time of delay, which ere is a function of the marginal cost of the firm. The inverse of this delay function, $t(c)$ will e denoted $c(t)$ and represents the inference of the agency as to the minimum marginal cost of ıe firm when a delay of time t is observed. In equilibrium this signal must be both credible nd accurate.

Price is determined in a manner consistent with the model used by Johnston and Zeckhauser. Once the agency has identified the costs of the firm through the signal it will ffer it a deal such that the firm is indifferent between accepting subsidisation or remaining nsubsidised. If a firm accepts subsidisation at time t it receives a price based on the revealed ost of the firm.[26] If the firm accepts subsidisation it agrees to price at a patient price of $p^c(t)$ and receive $p(t)-p^c(t)$ in subsidies. If a firm agrees to subsidisation at time t it thus eceives a price per unit of $p(t)$. Patients face a price of $p^c(t)$ and so demand $\mu(p^c(t))$. If a irm with marginal cost c accepts subsidisation it makes a profit of $(p(t)-c)\mu(p^c(t))$.

If a firm declines subsidisation it charges a price $\bar{p}$ and attracts a quantity $\bar{\mu}=\mu(\bar{p})$. The lefinition of $\bar{p}$ is best addressed at a later stage once the strategic effects of this choice are nown. A firm with marginal cost c makes a profit of $(\bar{p}-c)\bar{\mu}$. In equilibrium a signal of t mplies a (correct) belief by the agency that the firm has marginal costs of $c(t)$. The drug gency will offer only that payment sufficient to induce the firm to accept subsidisation.

$$(p(t)-c(t))\mu\left(p^c(t)\right)=\left(\bar{p}-c(t)\right)\bar{\mu}$$

$$p(t)\mu\left(p^c(t)\right)=\left(\bar{p}-c(t)\right)\bar{\mu}+c(t)\mu\left(p^c(t)\right)$$

$$p(t)=\bar{p}\frac{\bar{\mu}}{\mu\left(p^c(t)\right)}+c(t)\frac{\mu\left(p^c(t)\right)-\bar{\mu}}{\mu\left(p^c(t)\right)}$$

Now a firm accepting subsidisation at time t (where $t < T$) receives profits equal to:

$$\left(\bar{p}-c\right)\bar{\mu}\int_0^t e^{-rx}dx+(p(t)-c)\mu\left(p^c(t)\right)\int_t^T e^{-rx}dx.$$

---

benchmarks. This issue warrants further examination in order to ascertain the practicability of the JZ scheme.

[26] This price is composed of both the drug subsidy and any price paid by the patient.

This profit function extends only until generic entry for two reasons. Firstly the JZ amework should be engineered in such a way as to make subsidies re-negotiable on generic ıtry. Without such a move a generic would face having to enter the market against a firm ıarketing a superior drug and charging a consumer price of zero. Against such a foe no firm ·ould never enter. Secondly, because of the assumptions found to be necessary in Chapter 8 ıere is a constant difference between the quality of the incumbent and generic. The generic, ·ith a significant cost advantage, is expected to take the entire market. For this reason the ıcumbent is not expected to make profits beyond T and so the profit function ends here.

Each firm chooses the time it accepts subsidisation in order to maximise its profits so ıat:

$$\pi(c)=\max_{t}\left\{(\bar{p}-c)\bar{\mu}\int_{0}^{t}e^{-rx}dx+(p(t)-c)\mu\left(p^{c}(t)\right)\int_{t}^{T}e^{-rx}dx\right\}.$$

Now the for the signal $t(c)$ to be credible the optimal strategy for a firm with costs c nust be to delay a time $t(c)$. Rearranging the above profit equation:

$$\begin{aligned}
\tau(c) \quad &=\max_{t}\left\{(\bar{p}-c)\bar{\mu}\int_{0}^{t}e^{-rx}dx+(p(t)-c)\mu\left(p^{c}(t)\right)\int_{t}^{T}e^{-rx}dx\right\}\\
&=\max_{t}\left\{(\bar{p}-c)\bar{\mu}\int_{0}^{t}\mathrm{e}^{-rx}dx+\left(\bar{p}\frac{\bar{\mu}}{\mu\left(p^{c}(t)\right)}+c(t)\frac{\mu\left(p^{c}(t)\right)-\bar{\mu}}{\mu\left(p^{c}(t)\right)}-c\right)\mu\left(p^{c}(t)\right)\int_{t}^{T}\mathrm{e}^{-rx}dx\right\}\\
&=\max_{t}\left\{(\bar{p}-c)\bar{\mu}\int_{0}^{t}\mathrm{e}^{-rx}dx+\left(\overline{p\mu}+c(t)\left(\mu\left(p^{c}(t)\right)-\bar{\mu}\right)-c\mu\left(p^{c}(t)\right)\right)\int_{t}^{T}\mathrm{e}^{-rx}dx\right\}\\
&=\max_{t}\left\{(\bar{p}-c)\bar{\mu}\left[\tfrac{1}{r}-\tfrac{1}{r}\mathrm{e}^{-rt}\right]+\left(\overline{p\mu}+c(t)\left(\mu\left(p^{c}(t)\right)-\bar{\mu}\right)-c\mu\left(p^{c}(t)\right)\right)\left[\tfrac{1}{r}\mathrm{e}^{-rt}-\tfrac{1}{r}\mathrm{e}^{-rT}\right]\right\}
\end{aligned}$$

When the interior of this equation is differentiated in order to find the optimum value of t a differential equation is obtained.

$$\begin{aligned}
0=(\bar{p}-c)\bar{\mu}\mathrm{e}^{-rt}+\frac{dc}{dt}\left(\mu\left(p^{c}(t)\right)-\bar{\mu}\right)\left[\tfrac{1}{r}\mathrm{e}^{-rt}-\tfrac{1}{r}\mathrm{e}^{-rT}\right]+\left(c(t)\frac{d\mu}{dp^{c}}\frac{dp^{c}}{dt}-c\frac{d\mu}{dp^{c}}\frac{dp^{c}}{dt}\right)\left[\tfrac{1}{r}\mathrm{e}^{-rt}-\tfrac{1}{r}\mathrm{e}^{-rT}\right]\\
-\left(\overline{p\mu}+c(t)\left(\mu\left(p^{c}(t)\right)-\bar{\mu}\right)-c\mu\left(p^{c}(t)\right)\right)\mathrm{e}^{-rt}
\end{aligned}$$

In equilibrium the cost revelation function should be proved accurate. Were this not the case there must be an incentive for the subsidising agency to revise its beliefs in order to

educe subsidy payments. When this condition ($c = c(t)$) is incorporated into the previous quation the third term disappears while the final term is greatly simplified.

$$0 = \left(\bar{p} - c(t)\right)\bar{\mu}\,e^{-rt} + \frac{dc}{dt}\left(\mu\left(p^c(t)\right) - \bar{\mu}\right)\left[\frac{1}{r}e^{-rt} - \frac{1}{r}e^{-rT}\right] - \left(\bar{p} - c(t)\right)\bar{\mu}\,e^{-rt}$$

Now the first and last terms are identical so that:

$$0 = \frac{dc}{dt}\left(\mu\left(p^c(t)\right) - \bar{\mu}\right)\left[\frac{1}{r}e^{-rt} - \frac{1}{r}e^{-rT}\right]$$

Now this can be simplified to $dc/dt = 0$ where $\left(\mu\left(p^c(t)\right) - \bar{\mu}\right) \neq 0$ and $t \neq T$. These equirements are satisfied generally as when $\mu(p^c(t)) = \bar{\mu}$ there is no motivation for a ubsidisation scheme.[27] With $dc/dt = 0$ there can be no cost-discriminating signalling quilibrium as waiting to signal does not indicate a higher level of cost to the agency.

With $dc/dt = 0$ trivially $c(t) = A$. If the boundary condition $c(0) = 0$ is applied the cost evelation function becomes $c(t) = 0$. However long a firm delays before accepting ubsidisation the equilibrium conjecture of the agency does not change. The reason for this is elatively straightforward: the definition of $p(t)$ provides only the subsidy required to make a irm indifferent between joining the scheme or staying unsubsidised. This scheme does not nclude any motivation for a low cost firm to prefer that it signal its true cost sooner rather han later. A firm with marginal costs of zero is expected, in equilibrium, to wait an arbitrary ength of time until accepting subsidisation. However long a firm waits before accepting ubsidisation it cannot free itself from the expectation that it has marginal costs of zero.

An additional payment that decreases over time would give a low priced firm an incentive to signal early. If a firm was to signal late it can reasonably be assumed by the agency that it was not a low cost firm. The addition of a premium can then allow firms to credibly signal their true costs. The form of such a premium is completely arbitrary and it is acknowledged that no optimality necessarily follows the premiums used here. The differing premiums used for the zero and marginal cost charge sections were defined in their current

[27] Subsidisation is undertaken in order to lower the cost of drugs to patients. If $\mu(p^c(t)) = \bar{\mu}$ then the price charged to patients both before and after subsidisation is the same. Any worthwhile subsidy scheme must therefore have $\mu(p^c(t)) < \bar{\mu}$ for all $t<T$.

)rm because of their properties when evaluating the differential equation. The formation of ı optimal premium is another area left for further research.

Before proceeding it is necessary to first isolate the types of variants of the JZ scheme xplored here since each imposes different patient price schedules over time.[28] The simpler ase sees $p^c(t)=k$ so that both patient prices and the quantity demanded of the drug remains onstant over time. The second case sees $p^c(t)=c(t)$ so that the patient is levied with the ıarginal cost of the drug. In the latter case quantity demanded falls as the time to ubsidisation increases. Each of these schemes requires that a different premium be added to ıe price offered.

The above discussion on the problems faced under a signalling equilibrium is complete ut for an examination of one aspect of the effects of subsidisation - the effect of subsidisation n the consumer price of similar drugs. The JZ scheme analysed here results in a fixed greement over prices for subsidised drugs so that subsidised firms cannot react to changes in he price of competitors. The only possible reactions can then come from unsubsidised firms. \s will be outlined below there will be no unsubsidised firms under the JZ scheme in the omparisons of Chapter 10. Even though this is the case the effect of such changes is assessed n Appendix 9.3.

The situation assessed when comparing the JZ variant below with reference pricing in Chapter 10 will place new firms only in markets where all incumbents are subsidised. These comparisons assess the cost, consumer surplus and efficiency of both the JZ and RP schemes for a two firm example. The first step in each scenario will be to define the initial firm and letermine at what price it will be subsidised. Once subsidised the consumer price of this firm s fixed.[29] The entrant approaches the subsidising agency some time after subsidisation and so faces a situation where, regardless of its own price, it will face a constant price from each ncumbent firm. The following sections address the cases where patient prices are levied at oth a fixed charge and at marginal cost.

---

[28] Which in turn changes the form of the price function giving the simplest DE to solve.

[29] By assumption. Subsidies are expected to stay at a set level throughout the period before generic entry. Special provisions would have to be made in the case of high unanticipated inflation.

(1) Constant patient prices

Consider a scheme where the price offered to a drug agency includes an additional :emium for participation that decreases with time. Consumer prices are set a constant level :) regardless of the true cost of the firm being subsidised. A firm accepting subsidisation at me t receives a premium $\frac{\Delta}{r}\left[e^{-rt}-e^{-rT}\right]-K$ on the price a firm with costs $c(t)$ requires to make indifferent between accepting subsidisation or not.

Where there is an incumbent it is assumed to be firm 2 and it is also assumed that as an ıcumbent it has previously been subsidised (see above) and so has a consumer price of k. he quantities $\bar{\mu}$ and $\mu(k)$ are then $\mu_1(\bar{p},k)$ and $\mu_1(k,k)$ respectively. Where there is no ıcumbent the firm faces competition from no other quarter and so $\bar{\mu}$ and $\mu(k)$ are $1-F_1(\frac{\bar{p}}{L})$ and $-F_1(\frac{k}{L})$ respectively. These figures represent the proportion of consumers that find treatment worthwhile.[30] The total price offered to a firm accepting subsidisation at time t equals:

$$p(t)=\bar{p}\frac{\bar{\mu}}{\mu(k)}+c(t)\frac{\mu(k)-\bar{\mu}}{\mu(k)}+\frac{\Delta}{r}\left[e^{-rt}-e^{-rT}\right]-K$$

Now subsidisation here gives a benefit to the firm above that accruing to it when it is nsubsidised.

$$\begin{aligned}
:(c) &= \max_t\left\{(\bar{p}-c)\bar{\mu}\int_0^t e^{-rx}dx+(p(t)-c)\mu(k)\int_t^T e^{-rx}dx\right\}\\
&= \max_t\left\{(\bar{p}-c)\bar{\mu}\int_0^t e^{-rx}dx+\left(\bar{p}\frac{\bar{\mu}}{\mu(k)}+c(t)\frac{\mu(k)-\bar{\mu}}{\mu(k)}+\frac{\Delta}{r}\left[e^{-rt}-e^{-rT}\right]-K-c\right)\mu(k)\int_t^T e^{-rx}dx\right\}\\
&= \max_t\left\{(\bar{p}-c)\bar{\mu}\int_0^t e^{-rx}dx+\left(\overline{p\mu}+c(t)\left(\mu(k)-\bar{\mu}\right)-c\mu(k)+\frac{\Delta}{r}\left[e^{-rt}-e^{-rT}\right]\mu(k)-K\mu(k)\right)\int_t^T e^{-rx}dx\right\}\\
&= \max_t\left\{(\bar{p}-c)\bar{\mu}\left[\tfrac{1}{r}-\tfrac{1}{r}e^{-rt}\right]+\left(\overline{p\mu}+c(t)\left(\mu(k)-\bar{\mu}\right)-c\mu(k)+\frac{\Delta}{r}\left[e^{-rt}-e^{-rT}\right]\mu(k)-K\mu(k)\right)\left[\tfrac{1}{r}e^{-rt}-\tfrac{1}{r}e^{-rT}\right]\right\}\\
&= \max_t\left\{\begin{array}{l}(\bar{p}-c)\bar{\mu}\left[\tfrac{1}{r}-\tfrac{1}{r}e^{-rt}\right]+\left(\overline{p\mu}+c(t)\left(\mu(k)-\bar{\mu}\right)-c\mu(k)\right)\left[\tfrac{1}{r}e^{-rt}-\tfrac{1}{r}e^{-rT}\right]\\ +\ \left(\frac{\Delta}{r}\left[e^{-rt}-e^{-rT}\right]\mu(k)-K\mu(k)\right)\left[\tfrac{1}{r}e^{-rt}-\tfrac{1}{r}e^{-rT}\right]\end{array}\right\}
\end{aligned}$$

[30] In the simulation of these cases these figures were found not by appealing to F_1 explicitly but ather to $\mu_1(\bullet, L\lambda_2)$. Where $p_2 = L\lambda_2$ the definitions of each function are identical.

As before this expression can be differentiated to find the first order condition for the optimal choice of t:

$$0=(\bar{p}-c)\bar{\mu}e^{-rt}-\left(\overline{p\mu}+c(t)(\mu(k)-\bar{\mu})-c\mu(k)\right)e^{-rt}+\frac{dc}{dt}(\mu(k)-\bar{\mu})\left[\tfrac{1}{r}e^{-rt}-\tfrac{1}{r}e^{-rT}\right]$$
$$-\left(\frac{\Delta}{r}\left[e^{-rt}-e^{-rT}\right]\mu(k)-K\mu(k)\right)e^{-rt}-\Delta e^{-rt}\mu(k)\left[\tfrac{1}{r}e^{-rt}-\tfrac{1}{r}e^{-rT}\right]$$

$$0=(\bar{p}-c)\bar{\mu}e^{-rt}-\left(\overline{p\mu}+c(t)(\mu(k)-\bar{\mu})-c\mu(k)\right)e^{-rt}+\frac{dc}{dt}(\mu(k)-\bar{\mu})\left[\tfrac{1}{r}e^{-rt}-\tfrac{1}{r}e^{-rT}\right]$$
$$+K\mu(k)e^{-rt}-\frac{\Delta}{r}\mu(k)e^{-rt}\left[e^{-rt}-e^{-rT}\right]$$

ow with $c=c(t)$ this becomes:

$$0=(\bar{p}-c(t))\bar{\mu}e^{-rt}-\left(\overline{p\mu}-c(t)\bar{\mu}\right)e^{-rt}+\frac{dc}{dt}(\mu(k)-\bar{\mu})\left[\tfrac{1}{r}e^{-rt}-\tfrac{1}{r}e^{-rT}\right]$$
$$+K\mu(k)e^{-rt}-2\frac{\Delta}{r}\mu(k)e^{-rt}\left[e^{-rt}-e^{-rT}\right]$$

$$0=(\bar{p}-c(t))\bar{\mu}e^{-rt}-(\bar{p}-c(t))\bar{\mu}e^{-rt}+\frac{dc}{dt}(\mu(k)-\bar{\mu})\left[\tfrac{1}{r}e^{-rt}-\tfrac{1}{r}e^{-rT}\right]$$
$$+K\mu(k)e^{-rt}-2\Delta\mu(k)e^{-rt}\left[\tfrac{1}{r}e^{-rt}-\tfrac{1}{r}e^{-rT}\right]$$

The differential equation for the cost revelation function $c(t)$ is:

$$0=\frac{dc}{dt}(\mu(k)-\bar{\mu})\left[\tfrac{1}{r}e^{-rt}-\tfrac{1}{r}e^{-rT}\right]-2\Delta\mu(k)e^{-rt}\left[\tfrac{1}{r}e^{-rt}-\tfrac{1}{r}e^{-rT}\right]+K\mu(k)e^{-rt}$$

$$0=\frac{dc}{dt}-2\Delta\frac{\mu(k)e^{-rt}}{(\mu(k)-\bar{\mu})}+K\frac{r\mu(k)e^{-rt}}{(\mu(k)-\bar{\mu})(e^{-rt}-e^{-rT})}$$

$$\frac{dc}{dt}=\frac{2\Delta\mu(k)}{(\mu(k)-\bar{\mu})}e^{-rt}-\frac{K\mu(k)}{(\mu(k)-\bar{\mu})}\frac{re^{-rt}}{(e^{-rt}-e^{-rT})}$$

Cost is disclosed exponentially in time.

$$c(t)=-\frac{2\Delta}{r}\frac{\mu(k)}{(\mu(k)-\bar{\mu})}e^{-rt}+\frac{K\mu(k)}{(\mu(k)-\bar{\mu})}\log\left(e^{-rt}-e^{-rT}\right)+D$$

Imposing the boundary condition that $c(0)=0$ the final value of $c(t)$ can be found:

$$0=c(0)=-\frac{2\Delta}{r}\frac{\mu(k)}{(\mu(k)-\bar{\mu})}e^{-r0}+\frac{K\mu(k)}{(\mu(k)-\bar{\mu})}\log\left(e^{-r0}-e^{-rT}\right)+D$$

$$0=c(0)=-\frac{2\Delta}{r}\frac{\mu(k)}{(\mu(k)-\bar{\mu})}+\frac{K\mu(k)}{(\mu(k)-\bar{\mu})}\log\left(1-e^{-rT}\right)+D$$

$$D=\frac{2\Delta}{r}\frac{\mu(k)}{(\mu(k)-\bar{\mu})}-\frac{K\mu(k)}{(\mu(k)-\bar{\mu})}\log\left(1-e^{-rT}\right)$$

o that

$$c(t) = -\frac{2\Delta}{r}\frac{\mu(k)}{\left(\mu(k)-\bar{\mu}\right)}e^{-rt} + \frac{K\mu(k)}{\left(\mu(k)-\bar{\mu}\right)}\log\left(e^{-rt}-e^{-rT}\right)+D$$

$$c(t) = -\frac{2\Delta}{r}\frac{\mu(k)}{\left(\mu(k)-\bar{\mu}\right)}e^{-rt} + \frac{K\mu(k)}{\left(\mu(k)-\bar{\mu}\right)}\log\left(e^{-rt}-e^{-rT}\right)+\frac{2\Delta}{r}\frac{\mu(k)}{\left(\mu(k)-\bar{\mu}\right)} - \frac{K\mu(k)}{\left(\mu(k)-\bar{\mu}\right)}\log\left(1-e^{-rT}\right)$$

$$c(t) = \frac{2\Delta}{r}\frac{\mu(k)}{\left(\mu(k)-\bar{\mu}\right)}\left(1-e^{-rt}\right)+\frac{K\mu(k)}{\left(\mu(k)-\bar{\mu}\right)}\log\left(\frac{e^{-rt}-e^{-rT}}{1-e^{-rT}}\right).$$

The pharmaceutical agency chooses Δ and K in order to determine the precise makeup of he revelation function. The former of these variables controls the speed of entry of firms vhile the latter is used to control the payoff given to the final firm joining the scheme.

Some sort of operating restriction is necessary on the workings of the subsidising agency vith respect to the time taken to achieve subsidisation of pharmaceuticals. For the purposes of this thesis the restriction placed on the subsidising agency is assumed to be largely political n nature. A budgetary restriction had originally been envisaged for the definition of Δ and K but was abandoned as being unlikely[31] after Pharmac exceeded its budget in 1997. The restriction placed on the agency here is a function of political and health pressures.[32]

In New Zealand and elsewhere patients and their advocacy groups are likely to demand subsidisation of medicines deemed necessary to the health and welfare of patients. In New Zealand both the Aids Foundation and the Schizophrenia Fellowship, amongst others, have been vocal in their demands that different medicines are subsidised. Persistent pressure will tell on politicians sensitive to claims that patients are being denied access to important advances in medication. The agency is likely to have a limited time in which to subsidise drugs before pressure placed on them becomes more costly than the additional payments necessary to guarantee subsidisation.

---

[31] At least in New Zealand.

[32] A strict budgetary restriction would result in a different type of scheme. Under a budget-restricted scheme premium payments on offer would be defined as follows: the budget would be spent and ratio of the expected change in consumer surplus over the expected change in subsidy payments would be the same for all drugs. This corresponds to the condition for an individual maximising utility that a budget is met and the ratio of marginal utilities over price is equal between goods. The analysis of such a scheme is left for future research.

Pharmaceuticals represent a significant tool for the care of patients under both the public nd private health systems. The body in charge of the public health system will expect value or the money assigned to pharmaceutical subsidisation but will however place a value on urrently unsubsidised drugs. It would prefer to see all treatment options available as soon as ossible at the cheapest possible price. It appears reasonable that they too would begin to lace pressure on the subsidising agency if delays begin to grow beyond limits perceived to be easonable, particularly for drugs that may reduce expenditures elsewhere in the health sector.

These largely political pressures are likely to vary between drugs depending on the value hat the unsubsidised drug represents above existing treatment options.

As different patient interest groups have different degrees of political influence it is xpected that they will be able to exert differing amounts of pressure. As an example the New Zealand Heart Foundation may well be more powerful than, say, the Osteoporosis Society and o delays for coronary drugs may well be less than for osteoporosis. It is envisaged that the ubsidising agency will determine a threshold by which time firms of all possible marginal osts shall have accepted subsidisation.[33] Where this time threshold is given the symbol t^* hen it is expected that $c(t^*) = a$ where a is the highest possible level of marginal cost.

The firm with the largest possible marginal cost need not be offered any return in excess of that required to make it indifferent between accepting subsidisation or continuing in an unsubsidised fashion.[34] The premium above the indifference level for this firm is then zero:

$$0 = \frac{\Delta}{r}\left[e^{-rt^*} - e^{-rT}\right] - K$$

so that K is defined as:

$$K = \frac{\Delta}{r}\left[e^{-rt^*} - e^{-rT}\right].$$

---

[33] In equilibrium. The subsidising agency obviously cannot force acceptance.

[34] Firms with marginal costs below the maximum require a decreasing premium only so that hey can credibly show their costs. These firms receive a premium only so that firms with higher narginal costs may in turn credibly signal their true costs. Firms with the maximum possible narginal costs have no firms above them and so do not require a premium.

$$c(t)=\frac{2\Delta}{r}\frac{\mu(k)}{\left(\mu(k)-\overline{\mu}\right)}\left(1-e^{-rt}\right)+\frac{\mu(k)}{\left(\mu(k)-\overline{\mu}\right)}\frac{\Delta}{r}\left(e^{-rt^*}-e^{-rT}\right)\log\left(\frac{e^{-rt}-e^{-rT}}{1-e^{-rT}}\right)$$

$$c(t)=\frac{\Delta}{r}\frac{\mu(k)}{\left(\mu(k)-\overline{\mu}\right)}\left(2\left(1-e^{-rt}\right)+\left(e^{-rt^*}-e^{-rT}\right)\log\left(\frac{e^{-rt}-e^{-rT}}{1-e^{-rT}}\right)\right)$$

nd at time $t=t^*$

$$a=\frac{\Delta}{r}\frac{\mu(k)}{\left(\mu(k)-\overline{\mu}\right)}\left(2\left(1-e^{-rt^*}\right)+\left(e^{-rt^*}-e^{-rT}\right)\log\left(\frac{e^{-rt^*}-e^{-rT}}{1-e^{-rT}}\right)\right)$$

$$\Delta=\frac{ra\left(\mu(k)-\overline{\mu}\right)}{\mu(k)\left(2\left(1-e^{-rt^*}\right)+\left(e^{-rt^*}-e^{-rT}\right)\log\left(\frac{e^{-rt^*}-e^{-rT}}{1-e^{-rT}}\right)\right)}$$

The cost function can now be defined in terms of t^* only.

$$c(t)=\frac{\Delta}{r}\frac{\mu(k)}{\left(\mu(k)-\overline{\mu}\right)}\left(2\left(1-e^{-rt}\right)+\left(e^{-rt^*}-e^{-rT}\right)\log\left(\frac{e^{-rt}-e^{-rT}}{1-e^{-rT}}\right)\right)$$

$$c(t)=\frac{ra\mu(k)\left(\mu(k)-\overline{\mu}\right)\left(2\left(1-e^{-rt}\right)+\left(e^{-rt^*}-e^{-rT}\right)\log\left(\frac{e^{-rt}-e^{-rT}}{1-e^{-rT}}\right)\right)}{r\mu(k)\left(\mu(k)-\overline{\mu}\right)\left(2\left(1-e^{-rt^*}\right)+\left(e^{-rt^*}-e^{-rT}\right)\log\left(\frac{e^{-rt^*}-e^{-rT}}{1-e^{-rT}}\right)\right)}$$

$$c(t)=a\frac{\left(2\left(1-e^{-rt}\right)+\left(e^{-rt^*}-e^{-rT}\right)\log\left(\frac{e^{-rt}-e^{-rT}}{1-e^{-rT}}\right)\right)}{\left(2\left(1-e^{-rt^*}\right)+\left(e^{-rt^*}-e^{-rT}\right)\log\left(\frac{e^{-rt^*}-e^{-rT}}{1-e^{-rT}}\right)\right)}$$

An example of this function where T=5.98 and t^*=0.5 is given below:

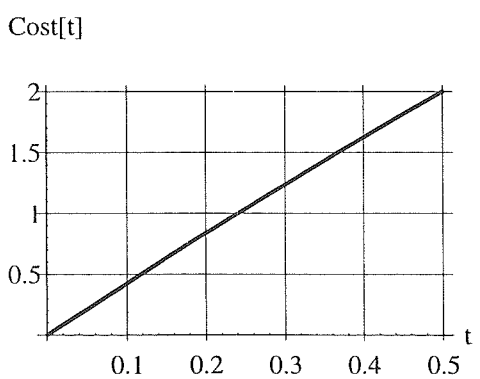


Figure 9.1: Cost revelation function (T=5.98, t*=0.50).

Note that the firm with the largest possible marginal costs can only credibly signal their ɔsts at the time threshold. This firm receives no premium above the price required to make it ıdifferent between accepting subsidisation or not. For the case without an incumbent firm 'here $\lambda_I = \eta_I = 1$ and $\bar{p} = 3.56098$ the relevant price function is displayed below.

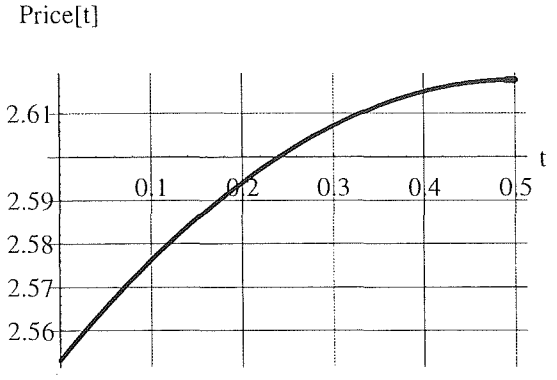


Figure 9.2: Sample price function.

Given the time threshold and the total time to generic entry,[35] in addition to the haracteristics of all drugs and the pre-subsidisation price of the drug to be subsidised a price unction like that in Figure 9.2 can be derived. The differential equation above has been reated so that the optimal decision of a firm with marginal costs c is to reveal its price at the ime where $c(t) = c$. Given the cost and price functions the expected outcome of any scenario :an be predicted.

A firm offered subsidisation under the JZ scheme has no control over any of the 'ariables that define the cost and price functions other than its own pre-subsidised price. The ïrm faces a choice over the value of this, and only this, variable. An important piece of erminology is introduced at this point. A firm's non-subsidisation optimum is taken to be the ïrm's optimum price were no subsidisation possible. A firm's pre-subsidisation price is its ɔptimum price given that the JZ variant outlined here is operating.

[35] Total time to generic entry in New Zealand is composed of four distinct factors: the effective ɔatent life of the drug, the delay after patent expiration before a generic applies for registration in New Zealand, the administrative delay in actually approving registration, and finally the time taken for Pharmac to arrange subsidisation of the generic.

If a firm was to charge away from its non-subsidisation optimum before being ıbsidised under the JZ scheme it faces two opposing effects. By pricing away from the ɔtimum it reduces its profits over the entire time period before generic entry. :e-subsidisation it receives smaller profits when pricing away from its non-subsidised ɔtimum. Lower pre-subsidisation profits also reduce the subsidy required to make a firm :different between joining the scheme or not. By pricing away from its non-subsidised ɔtimum a firm may also influence the values of Δ and K in order to increase the level of the :emium enjoyed in equilibrium.

In general the second factor outweighs the first and promotes a pre-subsidisation price way from the non-subsidised optimum. The value of Δ has previously been shown to be

$$\Delta = \frac{ra\left(\mu(k)-\overline{\mu}\right)}{\mu(k)\left(2\left(1-e^{-rt^*}\right)+\left(e^{-rt^*}-e^{-rT}\right)\log\left(\frac{e^{-rt^*}-e^{-rT}}{1-e^{-rT}}\right)\right)}$$

$$= \alpha\left(1-\frac{\overline{\mu}}{\mu(k)}\right)$$

here $\alpha = \dfrac{ra}{\left(2\left(1-e^{-rt^*}\right)+\left(e^{-rt^*}-e^{-rT}\right)\log\left(\frac{e^{-rt^*}-e^{-rT}}{1-e^{-rT}}\right)\right)}$.

Now K has previously been defined as a function of Δ so that:

$$K = \frac{\Delta}{r}\left[e^{-rt^*}-e^{-rT}\right] = \alpha\left(1-\frac{\overline{\mu}}{\mu(k)}\right)\left[\tfrac{1}{r}e^{-rt^*}-\tfrac{1}{r}e^{-rT}\right]$$

The premium to a firm accepting subsidisation at time t is then:

$$\frac{\Delta}{r}\left[e^{-rt}-e^{-rT}\right]-K$$

$$= \alpha\left(1-\frac{\overline{\mu}}{\mu(k)}\right)\left[\tfrac{1}{r}e^{-rt}-\tfrac{1}{r}e^{-rT}\right]-\alpha\left(1-\frac{\overline{\mu}}{\mu(k)}\right)\left[\tfrac{1}{r}e^{-rt^*}-\tfrac{1}{r}e^{-rT}\right]$$

$$= \alpha\left(1-\frac{\overline{\mu}}{\mu(k)}\right)\left[\tfrac{1}{r}e^{-rt}-\tfrac{1}{r}e^{-rt^*}\right]$$

A higher value of $\overline{p}$ reduces $\overline{\mu}=\mu(\overline{p})$ and increases the premium on offer to firms. A irm with marginal costs below the maximum possible level will price above its ıon-subsidisation optimum in order make increased profits over the time they are subsidised.

, firm with the maximum possible level of marginal costs will never receive a premium in quilibrium and so will not price above its non-subsidisation optimum.

The pre-subsidisation price is defined to be the price that optimises the discounted rofits of the firm over the entire period before generic entry. This completes the definition of ıe JZ variant where subsidised firms charge a fixed consumer price. Given the haracteristics and marginal costs of all firms a Nash Equilibrium for the JZ scheme can now ›e found.[36] This model is used as the alternative to reference pricing in the comparisons of he following chapter.

(2) Marginal cost pricing to patients

The proposed pricing scheme in this case is similar to that used for the fixed charge case ›ut here the premium is deflated by quantity.

$$p(t) = \bar{p}\frac{\bar{\mu}}{\mu(c(t))} + c(t)\frac{\mu(c(t)) - \bar{\mu}}{\mu(c(t))} + \frac{\Delta}{r}\frac{e^{-rt} - e^{-rT} - K}{\mu(c(t))}$$

Here the additional payment accruing to a firm accepting subsidisation is a fixed amount $\frac{\Delta}{r}\left[e^{-rt} - e^{-rT} - K\right]$ paid continuously from the time subsidisation is accepted (t) to the time the ›atent expires. Where there is an incumbent it is assumed to be firm 2 and it is also assumed hat, as an incumbent, it has been previously subsidised and charges a consumer price of c_2, its narginal cost. The quantities $\bar{\mu}$ and $\mu(c(t))$ are then $\mu_1(\bar{p}, c_2)$ and $\mu_1(c(t), c_2)$ respectively. Where there is no incumbent the firm faces competition from no other firm and so $\bar{\mu}$ and ı($c(t)$) are $1\text{-}F_1(\frac{\bar{p}}{L})$ and $1\text{-}F_1\left(\frac{c(t)}{L}\right)$ respectively. These figures represent the proportion of consumers that find treatment worthwhile.

The profit function of a firm with costs c under the signalling equilibrium where costs ıre revealed according to the function $c(t)$ is given below.

---

[36] Where drugs enter the market sequentially (with a sufficient delay) the initial drug is ›ubsidised. After some time has passed the second firm enters and is subsidised, while the other firm remains fully subsidised. Where two firms await subsidisation (which is not addressed by the dynamics above) it is envisaged that each will be subsidised at the level required to make it indifferent ›ver subsidisation, given that the other firm remains unsubsidised. This assumption should prevent exploitation of the prisoner's dilemma aspects of the JZ scheme that were suspected of causing problems in Australia.

$$(c) \quad = \max_t \left\{ (\bar{p}-c)\bar{\mu}\int_0^t e^{-rx}dx + (p(t)-c)\mu(c(t))\int_t^T e^{-rx}dx \right\}$$

$$= \max_t \left\{ (\bar{p}-c)\bar{\mu}\int_0^t e^{-rx}dx + \left(\bar{p}\frac{\bar{\mu}}{\mu(c(t))} + c(t)\frac{\mu(c(t))-\bar{\mu}}{\mu(c(t))} + \frac{\Delta}{r}\frac{e^{-rt}-e^{-rT}-K}{\mu(c(t))} - c \right)\mu(c(t))\int_t^T e^{-rx}dx \right\}$$

$$= \max_t \left\{ (\bar{p}-c)\bar{\mu}\int_0^t e^{-rx}dx + \left(\overline{p\mu} + c(t)\left(\mu(c(t))-\bar{\mu}\right) - c\mu(c(t)) + \frac{\Delta}{r}\left(e^{-rt}-e^{-rT}-K\right) \right)\int_t^T e^{-rx}dx \right\}$$

$$= \max_t \left\{ (\bar{p}-c)\bar{\mu}\left[\tfrac{1}{r}-\tfrac{1}{r}e^{-rt}\right] + \left(\overline{p\mu} + c(t)\left(\mu(c(t))-\bar{\mu}\right) - c\mu(c(t)) + \frac{\Delta}{r}\left(e^{-rt}-e^{-rT}-K\right) \right)\left[\tfrac{1}{r}e^{-rt}-\tfrac{1}{r}e^{-rT}\right] \right\}$$

The first order condition for this function (with respect to time) is:

$$0 = (\bar{p}-c)\bar{\mu}e^{-rt} + \frac{dc}{dt}(\mu(c(t))-\bar{\mu})\left[\tfrac{1}{r}e^{-rt}-\tfrac{1}{r}e^{-rT}\right] + (c(t)\frac{d\mu}{dc}\frac{dc}{t} - c\frac{d\mu}{dc}\frac{dc}{t})\left[\tfrac{1}{r}e^{-rt}-\tfrac{1}{r}e^{-rT}\right]$$
$$-(\overline{p\mu} + c(t)(\mu(c(t))-\bar{\mu}) - c\mu(c(t)))e^{-rt} + \tfrac{d}{dt}\left[\Delta\left[\tfrac{1}{r}e^{-rt}-\tfrac{1}{r}e^{-rT}-\tfrac{K}{r}\right]\left[\tfrac{1}{r}e^{-rt}-\tfrac{1}{r}e^{-rT}\right]\right]$$

Now $\tfrac{d}{dt}\left[\Delta\left[\tfrac{1}{r}e^{-rt}-\tfrac{1}{r}e^{-rT}-\tfrac{K}{r}\right]\left[\tfrac{1}{r}e^{-rt}-\tfrac{1}{r}e^{-rT}\right]\right] = -2\Delta e^{-rt}\left[\tfrac{1}{r}e^{-rt}-\tfrac{1}{r}e^{-rT}\right] + \Delta\tfrac{K}{r}e^{-rt}$

Evaluating the first terms in the DE above as before and adding the evaluation of the final term we obtain:

$$0 = \frac{dc}{dt}\left(\mu(c(t))-\bar{\mu}\right)\left(\tfrac{1}{r}e^{-rt}-\tfrac{1}{r}e^{-rT}\right) - 2\Delta e^{-rt}\left(\tfrac{1}{r}e^{-rt}-\tfrac{1}{r}e^{-rT}\right) + \Delta\tfrac{K}{r}e^{-rt}$$

$$0 = \frac{dc}{dt}\left(\mu(c(t))-\bar{\mu}\right) - 2\Delta e^{-rt} + \frac{\Delta K e^{-rt}}{e^{-rt}-e^{-rT}}$$

$$\frac{dc}{dt} = 2\frac{\Delta e^{-rt}}{\mu(c(t))-\bar{\mu}} - \frac{\Delta e^{-rt}}{\mu(c(t))-\bar{\mu}}\frac{K}{e^{-rt}-e^{-rT}}$$

$$\frac{dc}{dt} = \frac{\Delta e^{-rt}}{\mu(c(t))-\bar{\mu}}\left(2-\frac{K}{e^{-rt}-e^{-rT}}\right)$$

Now Δ and K retain the same purposes as in the constant consumer price case above. A critical value of t (t^*) is again defined which allows K to be adjusted so as to set the premium the highest marginal cost firm would receive to zero.

$$0 = \frac{\Delta}{r}\frac{e^{-rt^*}-e^{-rT}-K}{\mu(c(t))}$$

$$0 = e^{-rt^*}-e^{-rT}-K$$

$$K = e^{-rt^*} - e^{-rT}$$

So that now

$$\frac{dc}{dt} = \frac{\Delta e^{-rt}}{\mu(c(t)) - \overline{\mu}}\left(2 - \frac{e^{-rt^*} - e^{-rT}}{e^{-rt} - e^{-rT}}\right)$$

Since $\mu(c(t))$ is a piecewise function[37] this differential equation must be solved umerically with the restriction that $c(0) = 0$. For a given value of Δ an approximation of the ost function ($c_\Delta(t)$) is derived. The final cost function is determined by an iterative method /hich seeks to find the value of Δ that satisfies the equation:

$c_\Delta(t^*) = a$ where a is the maximum value.

Using this numerical method the optimum value of Δ is found for a particular $\overline{p}$. To ind the equilibrium a further iterative method is required to find the optimum value of the ire-subsidised price for the firm. Given the method outlined here the equilibrium can be ound for any situation where the characteristics and costs of all firms are known.

/. SUMMARY

The choice of the signalling equilibrium framework over that of screening equilibria is a esult of three distinct factors. Screening equilibria give non-unique solutions and require 'ery strong assumptions about the drug subsidising agency in order to give reasonable esults.[38] The signalling equilibrium framework gives a unique equilibrium for both constant ınd marginal cost pricing.

---

[37] From Appendix 5.1

$$\mu_1 = \begin{cases} \int_{\frac{p_1}{L}}^{\lambda_1} f_1(\varphi_1) F_2\left(\varphi_1 - \frac{(p_1 - p_2)}{L}\right) d\varphi_1 & \text{if } \lambda_1 - \frac{(p_1 - p_2)}{L} \le \lambda_2 \\ 1 - F_1\left(\lambda_2 + \frac{(p_1 - p_2)}{L}\right) + \int_{\frac{p_1}{L}}^{\lambda_2 + \frac{(p_1 - p_2)}{L}} f_1(\varphi_1) F_2\left(\varphi_1 - \frac{(p_1 - p_2)}{L}\right) d\varphi_1 & \text{if } \lambda_1 - \frac{(p_1 - p_2)}{L} > \lambda_2 \end{cases}$$

[38] The utility function of the pharmaceutical agency must be defined and known by all parties. The signalling equilibrium requires no such knowledge.

'he time taken to obtain results is a factor in selecting the signalling framework over the creening model since in the fixed price case the time taken to find the equilibrium outcome is elatively small.

The major reason signalling equilibria are used for analysis in the following chapter is hat they allow an analysis specific to the JZ scheme where costs are initially unknown by the ubsidising agency. Under a signalling equilibrium the JZ scheme can be applied (in an pproximate fashion) to firms once their costs are known whereas under a screening quilibrium the strategic advantages of the JZ scheme are totally ignored.

CHAPTER 10

A COMPARISON OF REFERENCE PRICING WITH A MODIFIED JZ SCHEME

The previous chapter analysed the modified JZ scheme that will be used in comparison to ıe status quo. The variant of the reference pricing system currently used must be analysed efore any meaningful comparisons may take place. Section I contains such an analysis while ections III to VIII contain the actual comparison of the two systems. The sensitivity of the nalysis to key variables is addressed in Section IX. Sections X and XI address the feasibility of ıarginal cost pricing and the effects of each framework on patent integrity. The limits of the omparison process and suggestions for extensions of this work are included in Section XIII.

It has not been feasible to compare the schemes for every possible value of cost so the omparisons contained in this chapter consider cases where $c_i \in \{0,1,2\}$, for $i=1,2$ only. To ompare schemes over every possible value of cost would be both time consuming and nnecessary. If one scheme is found to be superior to its alternatives at all nine addressed omparisons it is likely that this will be the case for sufficient points to make the scheme superior ıverall. A full comparison would be prohibitively time consuming since finding equilibria under eference pricing may take a considerable amount of time.

The previous chapter analysed a modified JZ scheme and proposed it to be an alternative to eference pricing. Two different types of systems were designed: one where consumers face a ixed charge (normally zero) for treatment regardless of the drug used and one where consumers ace the marginal cost of any drugs used in treatment. Both the fixed charge and marginal cost ıricing variants are possible under the JZ scheme but only the fixed charge system is available ınder reference pricing. The reason for this is best explained after the fixed charge comparison s completed as the problems of applying marginal cost pricing are clearer after examination of he prices expected under the zero price scheme.

REFERENCE PRICING FRAMEWORK

Chapter 6 considered a completely unrestricted form of reference pricing where firms were ree to change their price and could choose to be reference priced at any time. Pharmac appears o have changed their original operating procedures in two important ways.

Pharmac typically follows its published operating procedures and sets subsidies at the level f the lowest priced drug. Pharmac appears to be reluctant to retain the reference price at a given evel in the face of an increase in the price of the current reference priced drug.[1] An example of his modified rule lies in the case of Naprosyn. Roche attempted to increase the price of Naprosyn, a NSAID[2], by 20% to match the price of Voltaren which was the next lowest priced drug in that subgroup.[3] Roche rationalised this move by appealing to the need to recoup R&D expenditures. If Pharmac was to keep at least one firm fully subsidised in that subgroup it would need to increase its subsidy to match the new price of Naprosyn. Pharmac was reluctant to do so, David Moore reportedly stating that Roche's action 'effectively blocks attempts to make sure that here is at least one fully subsidised prescription medicine for each group of the non-steroidal anti-inflammatory drugs'. It is unclear what happened past this point but were such price movements allowable firms would enjoy the full benefits of the high prices reference pricing promotes in an unrestricted form.[4]

---

[1] Where the currently reference priced drug is the *only* reference priced drug.

[2] Non-steroidal anti-inflammatory drug.

[3] For 750 mg tablets only. That Roche only attempted to increase the price of one application from the range of Naprosyn may suggest that Roche was testing Pharmac's reaction to an increase in price from a reference priced drug. Naprosyn is currently fully subsidised (Feb 1998 Pharmaceutical Schedule) but it is not known whether this is a result of an increase in the subsidy for Naprosyn or a decrease in the price of Voltaren. If it is the former, Pharmac cannot now credibly state that it will not increase the subsidy. Pharmac's actions could be seen as establishing a positive probability that subsidies will not increase if the price of the reference priced drug increases.

[4] See Chapter 6.

Pharmac also use a tactic designed to prevent drugs from entering a subgroup and charging : a premium. In *Targeting Medicines: Rationalising Resources in New Zealand* Pharmac states ıat:[5]

> Also, when suppliers wish to have new pharmaceuticals subsidised which have the same or similar therapeutic effect as currently subsidised pharmaceuticals ... Pharmac negotiates a price lower than the existing subsidy for the sub group applying at the time, and then reduces the subsidy on all other drugs in the same therapeutic sub group to that price.

The latter restriction may be even more significant than the former since it impacts directly n the price at which a firm may be subsidised. A two drug case is again considered where the ıcumbent drug (denoted firm 2) initially charges at a producer price of P_2^o and a consumer price f zero.[6] It is assumed that the drug of the potential entrant (denoted firm 1) has been approved y the Ministry of Health and is preparing to enter the industry. This firm has the option of being ılly subsidised and entering as the reference priced drug or remaining unsubsidised and charging higher price. Since the subsidisation of the first drug in a subgroup is problematical under ɔference pricing a framework for subsidisation must be derived.

(1) Subsidisation of the first drug in a subgroup

Where a therapeutic subgroup is to be formed to accommodate a significant new drug a ıroblem arises as to the incentives of this new firm. The firm knows that regardless of the price hey and the agency agree upon they are assumed to face a consumer price of zero. The firm has ıo incentive to limit the demands it places upon the agency if it believes it will be subsidised. The agency must therefore dictate a general scheme of how subsidisation will take place. Reference pricing and the Johnston-Zeckhauser scheme are two examples of general schemes ısed to set subsidies although the former is not particularly useful in this case.

If the agency chooses either to ignore or not seek cost information it must offer the same ɔayment to all firms regardless of their true marginal cost. In order to make sure subsidisation

---

[5] Kletchko SL and others. *Targeting Medicines, Rationalising Resources in New Zealand.* p. 9. In ıt least one recent case Pharmac has subsidised a new chemical entity above the reference price level in ecognition of its superior status.

[6] As in Chapter 6 charges levied on drugs by intermediaries (wholesalers, pharmacists etc.) are gnored. The sensitivity tests later relax this assumption by adding a fixed patient charge and assessing he effects of a fixed charge.

:curs this payment must be sufficient to compensate the highest possible cost producer of the ıarmaceutical for joining the subsidy scheme.[7] The targeted firm would accept these terms as ey represent a payoff at least as great as that available if they remain unsubsidised. If the rgeted firm has costs less than the maximum possible cost they will make larger profits as a sult of subsidisation.

The agency may decide that discovering the marginal cost of the firm is worthwhile in rder to reduce subsidy payments. If this is the case it will pursue what amounts to the modified Z scheme analysed previously. The latter of these possibilities will promote the lowest initial :ference prices in a new therapeutic subgroup. It is assumed that the agency, in order to limit ıbsidies will opt for the second alternative. The level of the initial reference price found ırough the modified JZ scheme is given the symbol P_2^o.

It is acknowledged that this assumption may not necessarily be valid but it is pointed out ıat this assumption promotes the lowest reference prices beneath which new firms must price to nter the subsidy scheme. This reference price will then allow for the most conservative stimates of prices and subsidy costs under reference pricing. Comparisons between the JZ cheme and reference pricing, if biased, will then be biased towards reference pricing rather than ıe JZ scheme. While bias in these comparisons is never desirable it seems prudent to allow the ossible bias to lie in favour of the status quo. The use of the JZ scheme to generate starting alues also has the nice property that it allows a constant base for comparison as both schemes tart with the same price for the incumbent drug.

(2) The entry of a second firm into a new subgroup

The reaction function of each firm with respect to the price it charges can be derived given he characteristics of each drug and their marginal costs. By examining the reaction functions in onjunction with P_2^o it is possible to predict the outcome of subsidisation under reference pricing. Six general cases are considered in the following sections; these cases differ in the assumptions nade over the level of initial subsidisation and the degree to which the incumbent and entrant liffer.

[7] While the agency can choose to price above the level that guarantees that all firms are at least ndifferent between the schemes there is no reason for it to do so.

(a) Moderate difference between drugs and a low initial reference price.

Where drugs are either distributed identically or with only moderate differences there is a igh chance that a range of equilibria exist where prices are shared. These shared prices tend to e large and reflect the problems of an unrestricted scheme of reference pricing.[8] The outcome f reference pricing in this case is predicted in the Figure 10.1 below.[9]

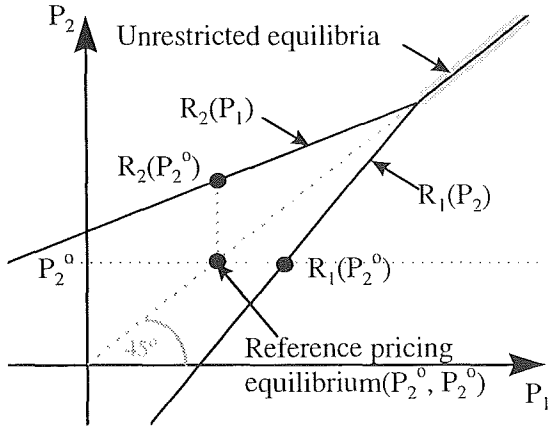


Figure 10.1: Very little difference between drugs and a low initial reference price.

Here firm 1 enters at price equal to the previous equilibrium price. Each firm has an ncentive to increase price since price here is less than that dictated by the firm's reaction unctions. Because of the restriction Pharmac places on the firms they are unable to increase heir price above P_2^o. Since neither firm has an incentive to decrease price the pricing strategies P_2^o, P_2^o) constitute a Nash Equilibrium.

A similar case to the above covers those situations where there is a unique equilibrium nder an unrestricted form of reference pricing but the point (P_2^o, P_2^o) is still a Nash Equilibrium n prices.[10] Figure 10.2 below displays this case. Note that while the unique equilibrium in the nrestricted case sees firms charging different prices this difference is not significant enough to notivate a difference in price under the restricted form of reference pricing. It is not significant

[8] See Chapter 6 for further details.

[9] Note that these cases deal only with stylised versions of reaction curves since the actual shape of these curves is not particularly important.

[10] This is typical of a case where moderate differences do exist between drugs.

ıat the diagram below shows a superior entrant (since $P_1^* > P_2^*$ where P_1^* and P_2^* are the ınrestricted equilibrium prices) as the result holds also for the case where the incumbent is ıoderately superior to the entrant.

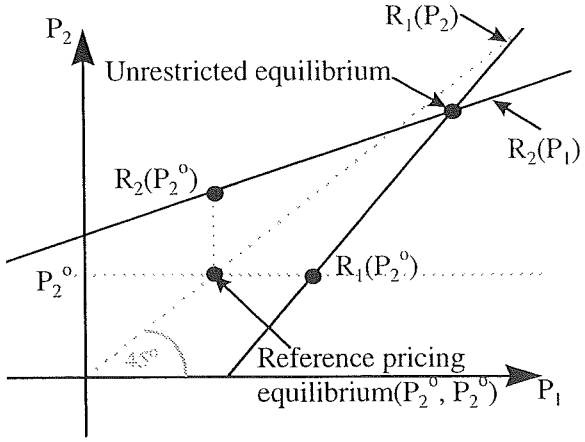


Figure 10.2: Moderate difference between drugs and a low initial reference price.

Each firm would again prefer to price above P_2^o but is unable to do so. Not wishing to ecrease price each will price at this level, resulting in a Nash Equilibrium of (P_2^o, P_2^o).

Both these case are identified by the identities $P_2^o \leq R_1(P_2^o)$ and $P_2^o \leq R_2(P_2^o)$.

(b) A strongly superior entrant and a low initial reference price.

Here the differences between drugs are large enough to motivate a premium for the entrant n equilibrium. Two different cases generate such a premium, the first of which requires a low nitial price and is typified by Figure 10.3.

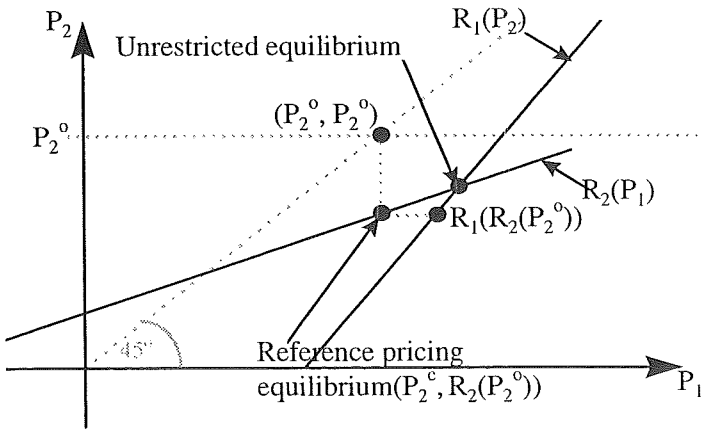


Figure 10.3: A strongly superior entrant and a low initial reference price.

The entrant here accepts subsidisation at the rate P_2^o. Where both firms charge at the ;ference price patients are free to choose any drug without paying a premium.[11] As a result of ıe entry of the new firm the incumbent, now competing with a strongly superior product at a ɔnsumer price of zero, perceives a large fall in quantity. The incumbent decreases its price to $_2(P_2^o)$ while the entrant, on perception of the incumbent's new price, wishes to increase its price ;om P_2^o to $R_1(R_2(P_2^o))$. The entrant still cannot freely increase price so it continues to price at P_2^o. ince prices do not shift from the point $(P_2^o, R_2(P_2^o))$ it represents a Nash Equilibrium in prices. 'his case is identified by $P_2^o \leq R_1(P_2^o)$, $P_2^o > R_2(P_2^o)$ and $P_2^o \leq R_1(R_2(P_2^o))$.

(c) A strongly superior entrant and a high initial reference price.

The second case giving a premium to the entrant is represented by Figure 10.4 below. Here he entrant enters at the previous reference price, prompting its competitor to decrease its price. n response to this decrease the entrant (firm 1) decreases its price, prompting a further price lecrease from the incumbent. The process of price reductions continues until the unrestricted ;quilibrium (P_1^*, P_2^*) is reached. This case is unlikely to be significant in the analysis of reference ɔricing to follow since it requires the initial subsidy to the incumbent firm to be high in relation o the prices involved in the unrestricted equilibrium.[12]

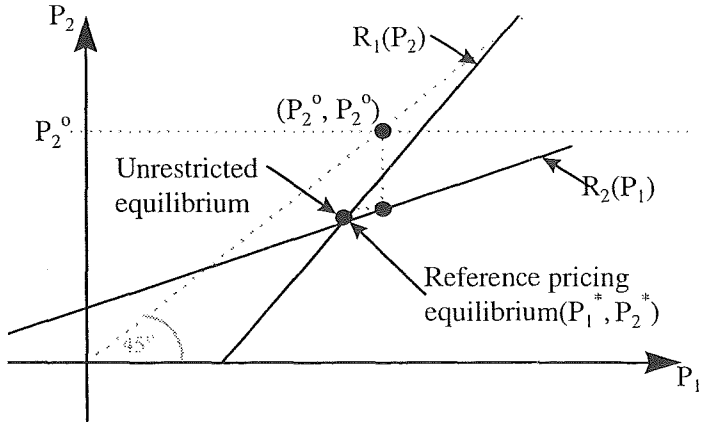


Figure 10.4: A strongly superior entrant and a high initial reference price.

[11] Pharmacists fees etc. are ignored as before.

[12] Since the JZ scheme allows for subsidisation at relatively low prices while Chapter 6 showed that prices under unrestricted forms of reference pricing tend to be high.

This case occurs where $P_2^o \leq R_1(P_2^o)$, $P_2^o > R_2(P_2^o)$ and $P_2^o > R_1(R_2(P_2^o))$.

(d) A strongly superior incumbent and a low initial reference price.

This case provides the opposite result to the previous one in that here the difference etween the drugs is sufficient to promote a higher price for the incumbent (who markets drug 2). ıs with the previous case of a superior entrant this case is divided into two scenarios. The ituation where P_2^o is low relative to the unrestricted equilibrium is addressed here. The ollowing section addresses the alternative scenario where P_2^o is assumed to be high.

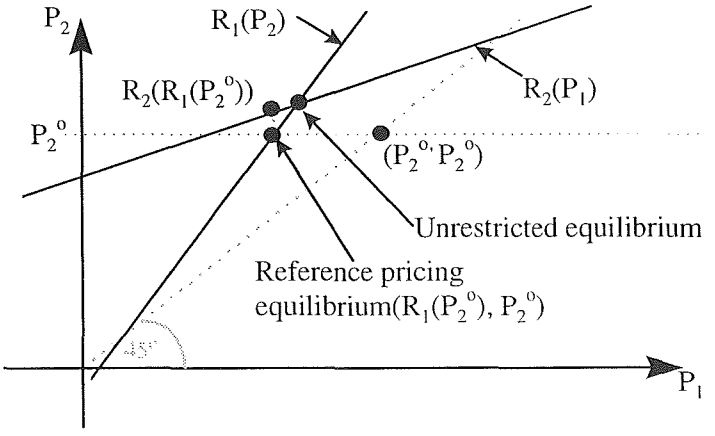


Figure 10.5: A strongly superior incumbent and a low initial reference price.

Here the entrant is subsidised below the previous reference price at p_2^0. The incumbent nay or may not have an incentive to decrease its price from this level. The case where the ncumbent will keep this price is given in the above diagram. This case has an equilibrium at $R_1(P_2^o), p_2^0)$ and is characterised by $P_2^o > R_1(P_2^o)$, $P_2^o \leq R_2(P_2^o)$ and $P_2^o \leq R_2(R_1(P_2^o))$.

(e) A strongly superior incumbent and a high initial reference price.

The alternative case to the above sees a series of lower prices leading to the unrestricted equilibrium being realised in the marketplace. This second case is characterised by $P_2^o > R_1(P_2^o)$, $P_2^o \leq R_2(P_2^o)$ and $P_2^o > R_2(R_1(P_2^o))$. This scenario is displayed on Figure 10.6 below.

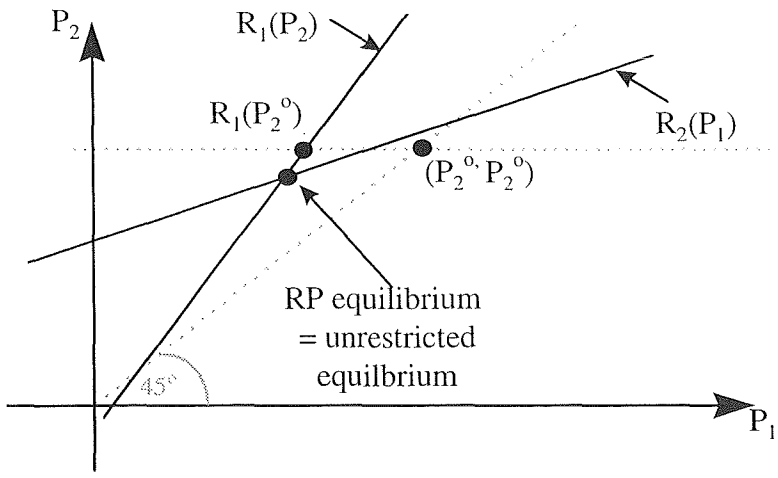


Figure 10.6: A strongly superior incumbent and a high initial reference price.

As with the case of a superior entrant and a high initial price equilibrium is achieved here by each firm reducing price to the level of the unrestricted equilibrium. The likelihood of such a case is again low since the JZ scheme keeps prices below the unsubsidised producer price.

(f) Very high initial subsidisation.

Previous cases have been identified using algebraic identities. All possible cases have been addressed but for the case where $P_2^o > R_1(P_2^o)$ and $P_2^o > R_2(P_2^o)$ which is included here for completeness only. This case requires that the point (P_2^o, P_2^o) involve prices so high that both firms would wish to decrease their producer price from this level. This case is extremely unlikely in practice due to the relatively small size of the pre-entry reference price within the subgroup. This case requires that the price the incumbent was awarded in order to accept reference pricing is higher than any observed under the unrestricted equilibrium. This case is displayed on Figure 10.7 and sees the unrestricted equilibrium occurring after a series of price decreases.

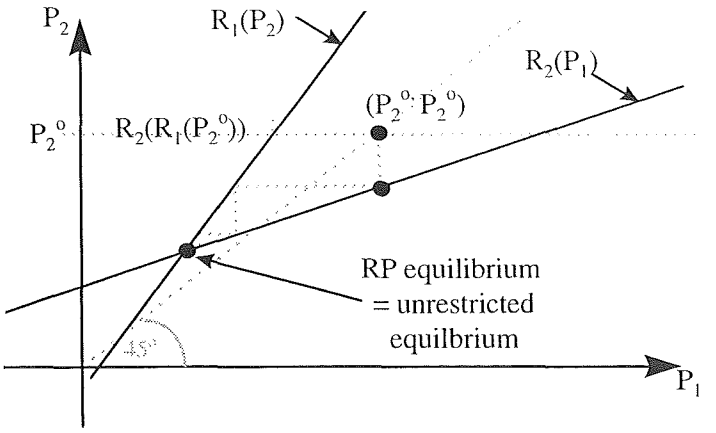


Figure 10.7: Very high initial subsidisation.

In summary the expected outcomes of each of these different cases is as follows:

P_2^o vs $R_1(P_2^o)$	P_2^o vs $R_2(P_2^o)$	P_2^o vs $R_1(R_2(P_2^o))$	P_2^o vs $R_2(R_1(P_2^o))$	P_1	P_2	Notes
:	≤	n/a	n/a	P_2^o	P_2^o	normal case: low P_2^o and little to moderate difference between drugs
:	>	≤	n/a	P_2^o	$R_2(P_2^o)$	strongly superior entrant - low P_2^o
:	>	>	n/a	P_1^*	P_2^*	strongly superior entrant - high P_2^o
>	≤	n/a	≤	$R_1(P_2^o)$	P_2^o	strongly superior incumbent - low P_2^o
>	≤	n/a	>	P_1^*	P_2^*	strongly superior incumbent - high P_2^o
>	>	n/a	n/a	P_1^*	P_2^*	high P_2^o and little difference between drugs

Table 10.1: Summary of cases under modified RP scheme.[13]

The previous sections have established the outcomes possible under reference pricing. These results will be used later when explaining the results of particular cases in the comparisons. The following section explores the method by which results were obtained. Of the reference pricing results it is expected that the majority of the cases will satisfy the conditions of the first row of Table 10.1. Here neither firm charges away from the pre-entry reference price. This is a direct result of the very high level of prices seen in the unrestricted form of reference pricing analysed in Chapter 6. The cases where a high level of the pre-entry reference price is required are likely to be extremely rare.

[13] Where P_1^* and P_2^* are the prices observed in the unrestricted RP equilibrium.

(g) Searching for the reference pricing equilibrium

The reference pricing equilibrium in each scenario was found by recursive calculation of ıe optimal price for each firm. Given the starting price P_2^o the price at which firm 1 enters the ıarket $P_1^1 = \min\{P_2^o, R_1(P_2^o)\}$ is calculated. Firm 2 is then given the chance to react and $_2^1 = \min\{P_1^1, R_2(P_1^1)\}$ is calculated. If both these figures equal P_2^o then the equilibrium is (P_2^o, P_2^o). If ot then the following program actions are performed until both P_1^t and P_2^t converge.

$P_1^t = \min\{P_2^{t-1}, R_1(P_2^{t-1})\}$

$P_2^t = \min\{P_1^{t-1}, R_2(P_1^{t-1})\}$

This sequence can be time consuming to calculate because each call to the reaction unction must be solved numerically.

I. JZ FRAMEWORK

The JZ scheme is analysed using the signalling equilibrium found in the previous chapter. t is assumed that, as with reference pricing, the incumbent has been previously subsidised. The ıntrant enters and prices at a pre-subsidisation price $\bar{p}$. The subsidising agency computes $c(t)$, $\rho(t)$ and $p^c(t)$ for the fixed charge scheme. At time 0 entry occurs and negotiations begin. Negotiations are expected to be completed by time $t^* = 0.50$. Subsidisation continues until time t' where generic entry occurs and subsidies are renegotiated. It is expected that the generic will ɔe successful in undercutting the incumbent in these subsidy negotiations.

II. NOTES ON THE COMPARISONS

The earlier chapters addressed four different cases covering identically distributed drugs, differences in efficacy, risk and a scenario where asymmetries in risk and efficacy approximately ɔalance. Each of these scenarios is duplicated in the following sections and include the results of subsidisation for the incumbent drug for different values of cost, the predicted behaviour under reference pricing and a comparison of reference pricing with the modified JZ scheme. In these comparisons and the sensitivity tests following them reference pricing is assumed to mean the

ariant outlined in Section I above. Where reference pricing in the unrestricted sense of Chapter is meant it is referred to as unrestricted reference pricing.

These comparisons assume that income (m) is 10, the loss in income due to illness (L) is 5, ıe time to generic entry (T) is 5.98 years, the interest rate is 10%, a uniform marginal cost istribution exists on [0, 2] and (for the JZ scheme) a maximum time to subsidisation of half a ear. These comparisons also assume that the subsidising agency desires subsidisation of these rugs. The value of the maximum time to subsidisation is of most concern here. While 0.50 ears has been used to approximate the time threshold it is acknowledged that, as a variable efined by political pressures, it is estimated best by the subsidising agency and may differ ignificantly between drugs.

The consumer surplus and subsidy figures given in the tables below are not per-period neasures but rather represent cumulative amounts over the period before generic entry. For the ɔurposes of the explanation below the instantaneous value of consumer surplus is represented by he function $CS(p_1^c, p_2^c)$. Now for the JZ scheme where k is the fixed charge to a subsidised drug normally $k = 0$) and t^* is actual delay to subsidisation consumer surplus is:

$$\mathrm{CS} = CS(\overline{p},k)\int_0^{t^*} \mathrm{e}^{-rx}dx + CS(k,k)\int_{t^*}^{T} \mathrm{e}^{-rx}dx.$$

Under the JZ scheme it is worthwhile to analyse quantity in order to simplify the :alculation of subsidy payments.. The JZ quantity and subsidy payments (where p_1 and p_2 are the ɔrices to firms one and two) are:

$$q_i = \mu_i(\overline{p},k)\int_0^{t^*} e^{-rx}dx + \mu_i(k,k)\int_{t^*}^{T} e^{-rx}dx$$

$$\text{subsidy} = (p_2 - k)q_2 + (p_1 - k)\mu_1(k,k)\int_{t^*}^{T} e^{-rx}dx$$

since subsidies are always paid for the incumbent throughout the period but only from t^* onwards for the entrant. The larger is cost the longer will be the delay to subsidisation and

ccordingly the lower will be consumer surplus. Subsidies may rise or fall for larger costs epending on whether the shorter subsidised period or the larger subsidised price dominate.

An entrant offered subsidisation under the reference pricing scheme will not delay in their hoice as the offer presented to them does not change over time. The quantity, subsidy and onsumer surplus figures for firms under reference pricing are:

$$q_i = \mu_i(k+\max(p_1-p_2,0),\ k+\max(p_2-p_1,0))\int_0^T e^{-rx}dx$$

$$\text{subsidy} = (\min(p_1,p_2)-k)(q_1+q_2)$$

$$CS = CS(k+\max(p_1-p_2,0),\ k+\max(p_2-p_1,0))\int_0^T e^{-rx}dx$$

vhere p_1, p_2 are the producer prices and k is the fixed charge under reference pricing.

Deadweight loss is not incorporated into the results because of concerns over the ıppropriateness of the 10% level used earlier. The comparison in Chapter 6 between reference ›ricing and the unregulated market under distortionary taxes is less relevant now than in Chapter 5 given the assumptions under reference pricing outlined above which reduce subsidy levels and he deadweight loss from subsidisation markedly.

V. IDENTICALLY DISTRIBUTED DRUGS

In this case $\lambda_1 = \lambda_2 = \eta_1 = \eta_2 = 1$ where drug 2 is assumed to be the incumbent drug. The following table gives (for the three addressed levels of cost) the signalled $\bar{p}$, the actual time to subsidisation (t^*), the maximum allowed time to subsidisation and the final subsidised price.

c	$\bar{p}$	t^*	$t_{\max}$	P_2^o
0	3.5610	0.0000	0.5000	2.5532
1	3.5722	0.2405	0.5000	2.6002
2	3.6067	0.5000	0.5000	2.6182

Table 10.2: Initial subsidisation of a drug with $\lambda = \eta = 1$.

Now under reference pricing the case of identically distributed sees a range of shared quilibrium prices under the unrestricted RP scheme. As predicted in Section a both firms harge at P_2^o under the modified RP framework defined above.

As defined for a firm with marginal cost c earlier the JZ scheme generates prices equal to:

$$p = c + \frac{\pi(\bar{p},0)}{\mu(0,0)}.$$

This price is independent of the costs of the second firm.[14] As with the RP case the consumer price of each drug under all nine JZ scenarios is zero. The following tables examine he outcomes of subsidisation under both the RP and JZ schemes as well as the outcome where he entrant remains unsubsidised. The outcomes of interest are producer prices (consumer prices n brackets), the subsidy payment required over the time to generic entry and the consumer urplus gained over that period. The delay before subsidisation occurs in the case of the JZ ariant is also given.

		Reference Pricing				JZ Variant					Only drug 2 subsidised			
c_1	c_2	p_1 (p_1^c)	p_2 (p_2^c)	subsidy ($m)	CS ($m)	p_1 (p_1^c)	p_2 (p_2^c)	subsidy ($m)	delay	CS ($m)	p_1 (p_1^c)	p_2 (p_2^c)	subsidy ($m)	CS ($m)
)	0	**2.55** (0.00)	2.55 (0.00)	**9.94**	12.78	2.31 (0.00)	2.55 (0.00)	9.46	0.00	12.78	2.39 (2.39)	2.55 (0.00)	6.68	9.43
	0	**2.55** (0.00)	2.55 (0.00)	**9.94**	12.78	2.37 (0.00)	2.55 (0.00)	9.44	0.24	12.56	2.95 (2.95)	2.55 (0.00)	6.90	8.99
)	0	**2.55** (0.00)	2.55 (0.00)	**9.94**	12.78	2.39 (0.00)	2.55 (0.00)	9.34	0.50	12.33	3.48 (3.48)	2.55 (0.00)	7.07	8.67
)	1	**2.60** (0.00)	2.60 (0.00)	**10.11**	12.78	2.31 (0.00)	2.60 (0.00)	9.56	0.00	12.78	2.39 (2.39)	2.60 (0.00)	6.80	9.43
	1	**2.60** (0.00)	2.60 (0.00)	**10.11**	12.78	2.37 (0.00)	2.60 (0.00)	9.54	0.24	12.56	2.95 (2.95)	2.60 (0.00)	7.03	8.99
)	1	**2.60** (0.00)	2.60 (0.00)	**10.11**	12.78	2.39 (0.00)	2.60 (0.00)	9.44	0.50	12.33	3.48 (3.48)	2.60 (0.00)	7.20	8.67
)	2	**2.62** (0.00)	2.62 (0.00)	**10.20**	12.78	2.31 (0.00)	2.62 (0.00)	9.59	0.00	12.78	2.39 (2.39)	2.62 (0.00)	6.85	9.43
	2	**2.62** (0.00)	2.62 (0.00)	**10.20**	12.78	2.37 (0.00)	2.62 (0.00)	9.57	0.24	12.56	2.95 (2.95)	2.62 (0.00)	7.08	8.99
)	2	**2.62** (0.00)	2.62 (0.00)	**10.20**	12.78	2.39 (0.00)	2.62 (0.00)	9.47	0.50	12.33	3.48 (3.48)	2.62 (0.00)	7.25	8.67

Table 10.3: Comparison of systems with identically distributed drugs.[15]

14 Regardless of the costs of the second firm the consumer price the entrant faces when unsubsidised is zero. It is the profits available when facing this consumer price that define the subsidy a firm gains.

15 Note that this table gives only the main results of the model for the purpose of comparison. The quantities each firm faces, the total surplus of each outcome and the $\bar{p}$ signalled by firm 1 in the JZ case are not given above for space reasons but do appear in the full tables in Appendix 10.1.

A convention that will be continued in future tables is introduced in Table 10.3 above. Where prices (be they consumer or producer prices) or subsidies under either RP or JZ are higher than their alternative they are displayed in bold type. Table 10.3 shows that producer prices are lower under the modified JZ scheme than reference pricing while both schemes provide drugs at zero cost to patients. The lower prices contribute to lower subsidy costs under the JZ scheme. Also leading to lower subsidy costs under JZ is the small delay experienced while a firm signals that it has positive costs. Subsidisation of drug 1 results both in increased costs to the government and significantly increased consumer surplus. In the case of identically distributed drugs the modified JZ scheme results in a consistently superior budgetary outcome at the cost of only a small delay.

Average decrease in subsidies (RP → JZ)	$ 0.59 m (5.87%)
Average decrease in CS (RP → JZ)	$ 0.22 m (1.72)
Average total surplus - RP	$ 8.88 m
Average total surplus - JZ	$ 8.75 m
Average change in total surplus (RP → JZ)	-$ 0.14 m

Table 10.4: Summary of schemes: identically distributed drugs

The 5.87% reduction in subsidies appears to outweigh the 1.72% reduction in consumer surplus that would occur in a switch to the modified JZ scheme. Total surplus would fall slightly were the reference pricing scheme to be abandoned because of the delay involved in subsidisation under the JZ scheme.

V. BALANCED ASYMMETRY

As the distribution of drugs differ in this case the comparison must take place in two parts. Section 1 assumes that the drug with $\lambda = 0.85, \eta = 1.10$ has been previously subsidised while Section 2 has the drug with $\lambda = 0.90, \eta = 1.00$ as the incumbent with the $\lambda = 0.85, \eta = 1.10$ drug entering the market.

(1) Balanced asymmetry (λ=0.85, η=1.10) previously subsidised.

Here drug 1 with characteristics $\lambda_1 = 0.90, \eta_1 = 1.00$ seeks subsidisation in a market where drug 2 is the incumbent drug (with characteristics $\lambda_2 = 0.85, \eta_2 = 1.10$). The following table gives

he equilibrium values of $\overline{p}$, the time to subsidisation, the maximum allowed time to ubsidisation and the final subsidised price for the initial subsidisation of drug 2.

c	$\overline{p}$	t^*	$t_{\max}$	P_2^o
0	3.1447	0.0000	0.5000	2.3381
1	3.1563	0.2405	0.5000	2.3883
2	3.1917	0.5000	0.5000	2.4075

Table 10.5: Initial subsidisation of a drug with $\lambda = 0.85$, $\eta = 1.10$.

Now under reference pricing the case of two drugs whose distributions are generally)alanced sees a range of shared equilibrium prices under the unrestricted RP scheme. As)redicted in Section a both firms choose to charge at P_2^o under the modified RP framework. The ollowing table gives the same general information as that given above in Table 10.3.

		Reference Pricing				JZ Variant					Only drug 2 subsidised			
ı	c_2	p_1 (p_1^c)	p_2 (p_2^c)	subsidy ($m)	CS ($m)	p_1 (p_1^c)	p_2 (p_2^c)	subsidy ($m)	delay	CS ($m)	p_1 (p_1^c)	p_2 (p_2^c)	subsidy ($m)	CS ($m)
	0	**2.34** (0.00)	2.34 (0.00)	**8.86**	10.67	2.21 (0.00)	2.34 (0.00)	8.63	0.00	10.67	2.14 (2.14)	2.34 (0.00)	5.98	7.72
	0	**2.34** (0.00)	2.34 (0.00)	**8.86**	10.67	2.27 (0.00)	2.34 (0.00)	8.61	0.24	10.48	2.69 (2.69)	2.34 (0.00)	6.18	7.29
	0	**2.34** (0.00)	2.34 (0.00)	**8.86**	10.67	2.29 (0.00)	2.34 (0.00)	8.51	0.50	10.27	3.23 (3.23)	2.34 (0.00)	6.30	6.99
	1	**2.39** (0.00)	2.39 (0.00)	**9.05**	10.67	2.21 (0.00)	2.39 (0.00)	8.73	0.00	10.67	2.14 (2.14)	2.39 (0.00)	6.11	7.72
	1	**2.39** (0.00)	2.39 (0.00)	**9.05**	10.67	2.27 (0.00)	2.39 (0.00)	8.70	0.24	10.48	2.69 (2.69)	2.39 (0.00)	6.31	7.29
	1	**2.39** (0.00)	2.39 (0.00)	**9.05**	10.67	2.29 (0.00)	2.39 (0.00)	8.61	0.50	10.27	3.23 (3.23)	2.39 (0.00)	6.44	6.99
	2	**2.41** (0.00)	2.41 (0.00)	**9.12**	10.67	2.21 (0.00)	2.41 (0.00)	8.76	0.00	10.67	2.14 (2.14)	2.41 (0.00)	6.16	7.72
	2	**2.41** (0.00)	2.41 (0.00)	**9.12**	10.67	2.27 (0.00)	2.41 (0.00)	8.74	0.24	10.48	2.69 (2.69)	2.41 (0.00)	6.36	7.29
	2	**2.41** (0.00)	2.41 (0.00)	**9.12**	10.67	2.29 (0.00)	2.41 (0.00)	8.65	0.50	10.27	3.23 (3.23)	2.41 (0.00)	6.49	6.99

Table 10.6: Comparison of systems with balanced asymmetry in distributions.[16]

As in the case of identical drugs where the distributions of the two drugs are 'close' to each)ther the JZ scheme results in lower prices and subsidy payments. Again the small delay in order o allow firms to credibly signal costs only affects consumer surplus slightly but provides an)pportunity to save a significant amount in subsidy payments. On average the decrease in ubsidy payments when moving from the JZ scheme to the RP scheme is 3.85% while the lecrease in consumer surplus is only 1.85%.

[16] See Appendix 10.1 for full table.

Average decrease in subsidies (RP → JZ)	$ 0.35 m (3.85%)
Average decrease in CS (RP → JZ)	$ 0.20 m (1.85%)
Average total surplus - RP	$ 6.89 m
Average total surplus - JZ	$ 6.77 m
Average change in total surplus (RP → JZ)	-$ 0.11 m

Table 10.7: Balanced asymmetry ($\lambda = 0.85,\ \eta = 1.10$ previously subsidised)

The lower subsidy costs associated with the JZ scheme again have their basis in lower prices than RP and a delay in the subsidisation of drugs. This delay prompts an efficiency comparison to favour reference pricing over the JZ scheme.

(2) Balanced asymmetry (λ=0.90, η=1.00) previously subsidised.

Here drug 1 with characteristics $\lambda_1 = 0.85, \eta_1 = 1.10$ seeks subsidisation where drug 2 is the incumbent drug (with characteristics $\lambda_2 = 0.90, \eta_2 = 1.00$). The following table gives the equilibrium values of $\overline{p}$, the time to subsidisation, the maximum allowed time to subsidisation and the final subsidised price for the initial subsidisation of drug 2.

c	$\overline{p}$	t^*	t_{max}	P_2^o
0	3.2779	0.0000	0.5000	2.3994
1	3.2894	0.2405	0.5000	2.4487
2	3.3248	0.5000	0.5000	2.4676

Table 10.8: Initial subsidisation of a drug with $\lambda = 0.90,\ \eta = 1.00$.

As with the previous balanced asymmetry case reference pricing sees both firms pricing at the pre-entry reference price. The following table gives the general information required for a comparison of the RP and JZ schemes.

		Reference Pricing				JZ Variant					Only drug 2 subsidised			
c_1	c_2	p_1 (p_1^c)	p_2 (p_2^c)	subsidy ($m)	CS ($m)	p_1 (p_1^c)	p_2 (p_2^c)	subsidy ($m)	delay	CS ($m)	p_1 (p_1^c)	p_2 (p_2^c)	subsidy ($m)	CS ($m)
0	0	**2.40** (0.00)	2.40 (0.00)	**9.09**	10.67	2.19 (0.00)	2.40 (0.00)	8.68	0.00	10.67	2.08 (2.08)	2.40 (0.00)	5.85	7.85
1	0	**2.40** (0.00)	2.40 (0.00)	**9.09**	10.67	2.25 (0.00)	2.40 (0.00)	8.66	0.24	10.49	2.61 (2.61)	2.40 (0.00)	6.07	7.44
2	0	**2.40** (0.00)	2.40 (0.00)	**9.09**	10.67	2.27 (0.00)	2.40 (0.00)	8.56	0.50	10.29	3.12 (3.12)	2.40 (0.00)	6.23	7.16
0	1	**2.45** (0.00)	2.45 (0.00)	**9.27**	10.67	2.19 (0.00)	2.45 (0.00)	8.77	0.00	10.67	2.08 (2.08)	2.45 (0.00)	5.96	7.85
1	1	**2.45** (0.00)	2.45 (0.00)	**9.27**	10.67	2.25 (0.00)	2.45 (0.00)	8.75	0.24	10.49	2.61 (2.61)	2.45 (0.00)	6.20	7.44
2	1	**2.45**	2.45	**9.27**	10.67	2.27	2.45	8.65	0.50	10.29	3.12	2.45	6.36	7.16

	(0.00)	(0.00)			(0.00)	(0.00)				(3.12)	(0.00)		
2	**2.47**	2.47	**9.35**	10.67	2.19	2.47	8.81	0.00	10.67	2.08	2.47	6.01	7.85
	(0.00)	(0.00)			(0.00)	(0.00)				(2.08)	(0.00)		
2	**2.47**	2.47	**9.35**	10.67	2.25	2.47	8.79	0.24	10.49	2.61	2.47	6.24	7.44
	(0.00)	(0.00)			(0.00)	(0.00)				(2.61)	(0.00)		
2	**2.47**	2.47	**9.35**	10.67	2.27	2.47	8.69	0.50	10.29	3.12	2.47	6.41	7.16
	(0.00)	(0.00)			(0.00)	(0.00)				(3.12)	(0.00)		

able 10.9: Comparison of systems with balanced asymmetry in distributions.[17]

Again the JZ scheme results in lower prices and subsidy payments when compared to the :ference pricing outcome. Delays are again small and provide an opportunity to save on subsidy ayments by allowing the agency to pay only what is necessary to firms.

Average decrease in subsidies (RP → JZ)	$ 0.57 m (5.74%)
Average decrease in CS (RP → JZ)	$ 0.19 m (1.77%)
Average total surplus - RP	$ 6.89 m
Average total surplus - JZ	$ 6.79 m
Average change in total surplus (RP → JZ)	-$ 0.09 m

'able 10.10: Balanced asymmetry ($\lambda = 0.90$, $\eta = 1.00$ **previously subsidised)**

Higher pre-entry reference prices lead to greater savings under the JZ scheme than in the revious comparison. In general, the case of a balanced asymmetry in drug distributions favours reference pricing scheme since efficiency tends to be higher here. Note that in order to gain igher efficiency under reference pricing greater subsidy payments are necessary in both alanced asymmetry scenarios.

'I. A DIFFERENCE IN EFFICACY.

As with the balanced asymmetry case the scenario addressing a difference in efficacy will eed to be compared in two parts, where both the inferior and superior drugs each are taken to be ıe incumbent firm. The case considered next subsidises the superior drug and then analyses the ffect of subsidising a markedly inferior drug. The second case (Section 2) compares the chemes where the inferior drug is the incumbent while the superior drug seeks subsidisation.

[17] See Appendix 10.1 for full table.

(1) Difference in efficacy (λ=1.00, η=1.00) previously subsidised.

Here drug 1 has characteristics $\lambda_1 = 0.50, \eta_1 = 1.00$ and seeks subsidisation in a market where drug 2 is the incumbent drug (with characteristics $\lambda_2 = 1.00, \eta_2 = 1.00$). The following table gives the equilibrium values of $\bar{p}$, the time to subsidisation, the maximum allowed time to subsidisation and the final subsidised price for the initial subsidisation of the superior drug 2.

c	$\bar{p}$	t^*	t_{max}	P_2^o
0	3.5610	0.0000	0.5000	2.5532
1	3.5722	0.2405	0.5000	2.6002
2	3.6067	0.5000	0.5000	2.6182

Table 10.11: Initial subsidisation of a drug with $\lambda = 1.00,\ \eta = 1.00$.

As with the previous three cases reference pricing sees the both drugs pricing at the pre-entry reference price under the modified RP framework. The following table gives the same general information as that given in previous tables above.

		Reference Pricing				JZ Variant					Only drug 2 subsidised			
c_1	c_2	p_1 (p_1^c)	p_2 (p_2^c)	subsidy ($m)	CS ($m)	p_1 (p_1^c)	p_2 (p_2^c)	subsidy ($m)	delay	CS ($m)	p_1 (p_1^c)	p_2 (p_2^c)	subsidy ($m)	CS ($m)
0	0	**2.55** (0.00)	2.55 (0.00)	**9.49**	9.34	1.93 (0.00)	2.55 (0.00)	8.60	0.00	9.34	1.24 (1.24)	2.55 (0.00)	6.70	8.55
1	0	**2.55** (0.00)	2.55 (0.00)	**9.49**	9.34	2.00 (0.00)	2.55 (0.00)	8.62	0.24	9.28	1.75 (1.75)	2.55 (0.00)	6.97	8.37
2	0	**2.55** (0.00)	2.55 (0.00)	**9.49**	9.34	2.02 (0.00)	2.55 (0.00)	8.57	0.50	9.22	2.25 (2.25)	2.55 (0.00)	7.18	8.29
0	1	**2.60** (0.00)	2.60 (0.00)	**9.66**	9.34	1.93 (0.00)	2.60 (0.00)	8.71	0.00	9.34	1.24 (1.24)	2.60 (0.00)	6.83	8.55
1	1	**2.60** (0.00)	2.60 (0.00)	**9.66**	9.34	2.00 (0.00)	2.60 (0.00)	8.73	0.24	9.28	1.75 (1.75)	2.60 (0.00)	7.09	8.37
2	1	**2.60** (0.00)	2.60 (0.00)	**9.66**	9.34	2.02 (0.00)	2.60 (0.00)	8.68	0.50	9.22	2.25 (2.25)	2.60 (0.00)	7.31	8.29
0	2	**2.62** (0.00)	2.62 (0.00)	**9.73**	9.34	1.93 (0.00)	2.62 (0.00)	8.75	0.00	9.34	1.24 (1.24)	2.62 (0.00)	6.87	8.55
1	2	**2.62** (0.00)	2.62 (0.00)	**9.73**	9.34	2.00 (0.00)	2.62 (0.00)	8.77	0.24	9.28	1.75 (1.75)	2.62 (0.00)	7.14	8.37
2	2	**2.62** (0.00)	2.62 (0.00)	**9.73**	9.34	2.02 (0.00)	2.62 (0.00)	8.72	0.50	9.22	2.25 (2.25)	2.62 (0.00)	7.36	8.29

Table 10.12: Comparison of systems with difference in efficacy.[18]

Once more the JZ scheme has delivered lower prices and subsidy payments. Under reference pricing the inferior drug is accorded the same rights as the superior drug in that each is

[18] See Appendix 10.1 for full table.

iven the right to charge at or below the pre-entry reference price and be fully subsidised. eference pricing is effectively blind to the different characteristics of each drug which makes ıe modified JZ scheme very attractive in this case. The JZ scheme represents an decrease of .8% in subsidy payments compared with reference pricing at a cost of only 0.6% of the ɔnsumer surplus attained under reference pricing. This case suggests more strongly than any revious case that the JZ scheme should be used in preference to reference pricing. A switch to ıe JZ scheme here would save a relatively large amount in subsidies while improving total ɹrplus.

Average decrease in subsidies (RP → JZ)	$ 0.93 m (9.84%)
Average decrease in CS (RP → JZ)	$ 0.06 m (0.60%)
Average total surplus - RP	$ 5.62 m
Average total surplus - JZ	$ 5.65 m
Average change in total surplus (RP → JZ)	$ 0.03 m

'able 10.13: Difference in efficacy ($\lambda = 1.00,\ \eta = 1.00$ **previously subsidised)**

Note however that it is doubtful that Pharmac would desire to subsidise such a drug since it ; both relatively ineffective and expensive. The price of drug 1 barely affects consumer surplus since it has low usage) and so committing funds to such a drug may be unlikely in an nvironment where money is scarce. Subsidisation is doubtful even under the JZ scheme as an verage increase in consumer surplus of $ 0.88 m is unlikely to warrant an additional cost of 1.63 m to the taxpayer. Total surplus would however favour the JZ scheme were subsidisation ɔ take place.

The difference in efficacy above was large enough to favour the JZ scheme over reference ɔricing. Appendix 10.3 analyses where this is the case and finds that where $\lambda_1 = 1, \lambda_2 > 0.62$, and $\eta_i = 1$ reference pricing is expected to be superior than the JZ variant. Where the difference in efficacy is greater than 0.38 the JZ scheme is favoured above RP.

(2) Difference in efficacy ($\lambda = 0.50,\ \eta = 1.00$) previously subsidised.

Here drug 1 has characteristics $\lambda_1 = 1.00, \eta_1 = 1.00$ seeks subsidisation where drug 2 is the ncumbent drug (with characteristics $\lambda_2 = 0.50, \eta_2 = 1.00$). The following table gives the

quilibrium values of $\bar{p}$, the time to subsidisation, the maximum allowed time to subsidisation nd the final subsidised price for the initial subsidisation of the superior drug 2.

c	$\bar{p}$	t^*	t_{max}	P_2^o
0	2.2013	0.0000	0.5000	1.9389
1	2.2140	0.2405	0.5000	2.0053
2	2.2531	0.5000	0.5000	2.0310

Table 10.14: Initial subsidisation of a drug with $\lambda = 0.50,\ \eta = 1.00$.

As with the three previous case reference pricing sees the both drugs pricing at the pre-ntry reference price under the modified RP framework. The following table gives the same eneral information as that given in previous tables above.

	Reference Pricing				JZ Variant					Only drug 2 subsidised			
c_2	p_1 (p_1^c)	p_2 (p_2^c)	subsidy ($m)	CS ($m)	p_1 (p_1^c)	p_2 (p_2^c)	subsidy ($m)	delay	CS ($m)	p_1 (p_1^c)	p_2 (p_2^c)	subsidy ($m)	CS ($m)
0	1.94 (0.00)	1.94 (0.00)	7.21	9.34	**2.25** (0.00)	1.94 (0.00)	**7.91**	0.00	9.34	1.93 (1.93)	1.94 (0.00)	4.06	5.04
0	1.94 (0.00)	1.94 (0.00)	7.21	9.34	**2.31** (0.00)	1.94 (0.00)	**7.85**	0.24	9.00	2.95 (2.95)	1.94 (0.00)	4.43	3.57
0	*NO SUBSIDISATION only drug 2 subsidised in eqm.*				2.33 (0.00)	1.94 (0.00)	7.69	0.50	8.65	3.48 (3.48)	1.94 (0.00)	4.25	3.04
1	2.01 (0.00)	2.01 (0.00)	7.45	9.34	**2.25** (0.00)	2.01 (0.00)	**8.01**	0.00	9.34	1.93 (1.93)	2.01 (0.00)	4.20	5.04
1	2.01 (0.00)	2.01 (0.00)	7.45	9.34	**2.31** (0.00)	2.01 (0.00)	**7.95**	0.24	9.00	2.95 (2.95)	2.01 (0.00)	4.58	3.57
1	*NO SUBSIDISATION only drug 2 subsidised in eqm.*				2.33 (0.00)	2.01 (0.00)	7.79	0.50	8.65	3.48 (3.48)	2.01 (0.00)	4.39	3.04
2	2.03 (0.00)	2.03 (0.00)	7.55	9.34	**2.25** (0.00)	2.03 (0.00)	**8.05**	0.00	9.34	1.93 (1.93)	2.03 (0.00)	4.25	5.04
2	2.03 (0.00)	2.03 (0.00)	7.55	9.34	**2.31** (0.00)	2.03 (0.00)	**7.99**	0.24	9.00	2.95 (2.95)	2.03 (0.00)	4.64	3.57
2	*NO SUBSIDISATION only drug 2 subsidised in eqm.*				2.33 (0.00)	2.03 (0.00)	8.65	0.50	8.65	3.48 (3.48)	2.03 (0.00)	4.45	3.04

Table 10.15: Comparison of systems with difference in efficacy.[19]

One of the fundamental tenets of a subsidisation scheme should be that it can reliably subsidise a worthwhile drug. In this case a drug which is highly effective compared to all alternatives may be effectively denied subsidisation on the grounds that its marginal cost is too high. Reference pricing does not consider differences in quality between drugs but simply treats all drugs in exactly the same manner. In the case of a difference in efficacy the very low payments made to drug 2 in order to prompt subsidisation make it possible that a firm chooses

[19] See Appendix 10.1 for full table.

)t to join the subsidisation scheme. Where $c_2 = 0$ subsidisation under reference pricing occurs and only if $c_1 > 1.48$ leaving over a 25% chance that drug representing a large improvement in eatment will not be subsidised. Where $c_2 = 1$ this threshold figure becomes 1.57 leaving over a)% chance that subsidisation will not occur. Even where $c_2 = 2$ subsidisation is not certain with nly 80% of firms taking up the offer to join.

The modified JZ scheme recognises the differences between drugs and pays a premium to ıose drugs that are superior. All firms will be subsidised at all possible levels of cost for the ıcumbent because the JZ scheme makes certain that all firms are at least indifferent between :cepting subsidisation or not. This necessitates that the JZ scheme offer a higher price to ıperior drugs which increases the cost of subsidisation. This can be seen above in the higher rices offered to the entrant in the cases where reference pricing results in subsidisation.

While the JZ scheme has not delivered lower prices and subsidy payments in this case it as delivered subsidisation of the targeted drug. Reference pricing in this case acts to the etriment of the superior drug, placing it in a worse position than if no framework existed at all.

Average decrease in subsidies (RP → JZ)	-$ 1.50 m (23.55%)
Average decrease in CS (RP → JZ)	-$ 1.76 m (24.36%)
Average total surplus - RP	$ 5.04 m
Average total surplus - JZ	$ 5.40 m
Average change in total surplus (RP → JZ)	$ 0.36 m

Table 10.16: Difference in efficacy ($\lambda = 0.50$, $\eta = 1.00$ **previously subsidised)**[20]

An increase in consumer surplus of 24.36% is possible under the JZ scheme at an increased ubsidy cost of $1.50 m. The cases where reference pricing fails to give sufficient returns to ırompt subsidisation of the entrant are the major reason for the moderate increase in total surplus ıvailable through switching to the JZ scheme here. The non-subsidisation of the entrant reduced :onsumer surplus under reference pricing, which was significant in the total surplus comparison. n general, this case has to be said to favour the JZ scheme over reference pricing for the reasons)f superior efficiency and the guarantee that the JZ scheme will deliver subsidisation.

[20] Non-subsidised values used in place of reference pricing for applicable scenarios.

II. DIFFERENCE IN RISK

As with previous cases the comparison between reference pricing and the modified ohnston-Zeckhauser scheme must take place in two parts. Section 1 assumes that the drug with $= 1.00, \eta = 5.00$ has been previously subsidised first while Section 2 has the drug with the quality istribution characterised by $\lambda = 1.00, \eta = 1.00$ as the incumbent with the superior drug seeking to ıter the subgroup.

(1) Difference in risk with ($\lambda = 1.00$, $\eta = 5.00$) previously subsidised.

Here drug 1 with characteristics $\lambda_1 = 1.00, \eta_1 = 1.00$ seeks to enter the subgroup where a ıarkedly superior drug 2 is the incumbent (drug 2 has characteristics $\lambda_2 = 1.00, \eta_2 = 5.00$). The ollowing table gives the equilibrium values of $\bar{p}$, the time to subsidisation, the maximum llowed time to subsidisation and the final subsidised price for the initial subsidisation of drug 2.

c	$\bar{p}$	t^*	t_{max}	P_2^o
0	3.8994	0.0000	0.5000	3.2412
1	3.9060	0.2405	0.5000	3.2667
2	3.9263	0.5000	0.5000	3.2766

Table 10.17: Initial subsidisation of a drug with $\lambda = 1.00$, $\eta = 5.00$.

This case is the first considered where the entrant chooses to price below P_2^o when ccepting subsidisation. The general behaviour exhibited by firms in this case under reference ıricing follows the pattern of Figure 10.5. All nine considered scenarios see the incumbent ontinuing to charge at the pre-entry reference price while the entrant, trying to compete with a ar superior drug, undercuts in order to gain market share. The entrant's undercutting implies hat the use of drug 2 attracts a positive charge while, being reference priced, drug 1 remains free o the consumer.[21] The marginal cost of drug 1 is significant in the definition of its reaction unction so that the price the entrant charges is dependant on its cost. Firm 1 needs not delay to ignal its true cost because regardless of its true cost it has no incentive to misrepresent this igure. Such a misrepresentation would simply decrease its profits.

[21] Recall that pharmacists fees etc. are ignored.

	Reference Pricing				JZ Variant					Only drug 2 subsidised			
c_2	p_1 (p_1^c)	p_2 (p_2^c)	subsidy ($m)	CS ($m)	p_1 (p_1^c)	p_2 (p_2^c)	subsidy ($m)	delay	CS ($m)	p_1 (p_1^c)	p_2 (p_2^c)	subsidy ($m)	CS ($m)
0	**2.28** (0.00)	3.24 **(0.96)**	10.20	15.50	1.94 (0.00)	3.24 (0.00)	**13.58**	0.00	18.76	0.99 (0.99)	3.24 (0.00)	13.65	18.29
0	**2.70** (0.00)	3.24 **(0.55)**	12.08	16.83	2.02 (0.00)	3.24 (0.00)	**13.68**	0.24	18.73	1.97 (1.97)	3.24 (0.00)	14.20	18.12
0	**3.13** (0.00)	3.24 **(0.11)**	**14.06**	18.36	2.05 (0.00)	3.24 (0.00)	13.74	0.50	18.69	2.90 (2.90)	3.24 (0.00)	14.40	18.06
1	**2.30** (0.00)	3.27 **(0.97)**	10.27	15.47	1.94 (0.00)	3.27 (0.00)	**13.68**	0.00	18.76	0.99 (0.99)	3.27 (0.00)	13.76	18.29
1	**2.71** (0.00)	3.27 **(0.56)**	12.14	16.79	2.02 (0.00)	3.27 (0.00)	**13.77**	0.24	18.73	1.97 (1.97)	3.27 (0.00)	14.32	18.12
1	**3.15** (0.00)	3.27 **(0.12)**	**14.12**	18.32	2.05 (0.00)	3.27 (0.00)	13.84	0.50	18.69	2.90 (2.90)	3.27 (0.00)	14.52	18.06
2	**2.30** (0.00)	3.28 **(0.97)**	10.29	15.46	1.94 (0.00)	3.28 (0.00)	**13.71**	0.00	18.76	0.99 (0.99)	3.28 (0.00)	13.80	18.29
2	**2.72** (0.00)	3.28 **(0.56)**	12.26	16.83	2.02 (0.00)	3.28 (0.00)	**13.81**	0.24	18.73	1.97 (1.97)	3.28 (0.00)	14.36	18.12
2	**3.15** (0.00)	3.28 **(0.12)**	**14.15**	18.30	2.05 (0.00)	3.28 (0.00)	13.87	0.50	18.69	2.90 (2.90)	3.28 (0.00)	14.56	18.06

able 10.18: Comparison of systems with a difference in risk (superior firm subsidised).[22]

The JZ scheme delivers lower producer prices than reference pricing. Consumer prices are ero under JZ but positive for drug 2 under reference pricing. As a result of this positive charge ıe subsidy payments for drug 2 are generally smaller under reference pricing.

The scheme judged superior in this case depends on the criterion that any comparison ocuses on. If either total surplus or subsidy expenditures is the main measure used, reference ricing is found to be superior since marginally higher average total surpluses and lower ubsidies arise here. If consumer surplus is judged as more important than subsidies then the JZ cheme is favoured. On balance the comparison used here favours the JZ scheme above eference pricing since the proportionate increase in consumer surplus is of the same magnitude s the increase in subsidies. The extra expenditure the JZ scheme requires of the taxpayer does ot increase the average price for treatment greatly. As this comparison relies on a subjective udgement over the average price of each scheme it is weighted slightly less than the other cases n the overall comparison.

[22] See Appendix 10.1 for full table.

Average decrease in subsidies (RP → JZ)	-$ 1.57 m (-12.88%)
Average decrease in CS (RP → JZ)	-$ 1.85 m (-10.97%)
Average total surplus - RP	$ 14.33 m
Average total surplus - JZ	$ 14.26 m
Average change in total surplus (RP → JZ)	-$ 0.06 m

'able 10.19: Difference in risk ($\lambda = 1.00,\ \eta = 5.00$ previously subsidised)[23]

An interesting point in this example is the question of whether subsidisation would occur nder reference pricing. The subsidisation of drug 1 under this scheme cuts subsidisation costs reatly while harming consumer surplus. If the pharmaceutical agency wishes to reduce the cost f subsidisation it is possible that consumer surplus will be sacrificed. Under the JZ scheme this /ill not be a temptation for the agency since consumer surplus rises and subsidy costs fall as a :sult of the subsidisation of drug 1.

(2) Difference in risk with ($\lambda = 1.00,\ \eta = 1.00$) previously subsidised.

Here the superior drug 1 (with characteristics $\lambda_1 = 1.00, \eta_1 = 5.00$) seeks subsidisation where rug 2 (characterised by $\lambda_2 = 1.00, \eta_2 = 1.00$) is the incumbent. The following table gives the quilibrium values of $\overline{p}$, the time to subsidisation, the maximum allowed time to subsidisation nd the final subsidised price for the initial subsidisation of drug 2.

c	$\overline{p}$	t^*	t_{max}	P_2^o
0	3.5610	0.0000	0.5000	2.5532
1	3.5722	0.2405	0.5000	2.6002
2	3.6067	0.5000	0.5000	2.6182

Table 10.20: Initial subsidisation of a drug with $\lambda = 1.00,\ \eta = 1.00$.

As in the previous section reference pricing normally results in the two firms charging lifferent rates with the superior firm pricing at a higher rate. The type of situation covering the irst six cases is that displayed on Figure 10.7 where the incumbent reduces price in response to

[23] Non-subsidised values used in place of reference pricing for applicable scenarios.

try but the entrant does not reduce its price below the pre-entry reference price. The final three enarios follow the more usual case where both firms charge at the pre-entry reference price.

	Reference Pricing				JZ Variant					Only drug 2 subsidised			
c_2	p_1 (p_1^c)	p_2 (p_2^c)	subsidy ($m)	CS ($m)	p_1 (p_1^c)	p_2 (p_2^c)	subsidy ($m)	delay	CS ($m)	p_1 (p_1^c)	p_2 (p_2^c)	subsidy ($m)	CS ($m)
0	2.55 **(0.68)**	1.88 (0.00)	8.40	16.40	**2.58** (0.00)	**2.55** (0.00)	**11.55**	0.00	18.76	3.05 (3.05)	2.55 (0.00)	6.19	10.39
0	2.55 **(0.68)**	1.88 (0.00)	8.40	16.40	**2.63** (0.00)	**2.55** (0.00)	**11.47**	0.24	18.26	3.42 (3.42)	2.55 (0.00)	6.52	9.74
0	*NO SUBSIDISATION only drug 2 subsidised in eqm.*				2.64 (0.00)	2.55 (0.00)	11.26	0.50	17.73	3.78 (3.78)	2.55 (0.00)	6.79	9.21
1	**2.60** **(0.27)**	2.33 (0.00)	10.46	17.79	2.58 (0.00)	**2.60** (0.00)	**11.59**	0.00	18.76	3.05 (3.05)	2.60 (0.00)	6.30	10.39
1	2.60 **(0.27)**	2.33 (0.00)	10.46	17.79	**2.63** (0.00)	**2.60** (0.00)	**11.51**	0.24	18.26	3.42 (3.42)	2.60 (0.00)	6.64	9.74
1	*NO SUBSIDISATION only drug 2 subsidised in eqm.*				2.64 (0.00)	2.60 (0.00)	11.30	0.50	17.73	3.78 (3.78)	2.60 (0.00)	6.91	9.21
2	**2.62** (0.00)	2.62 (0.00)	**11.75**	18.76	2.58 (0.00)	2.62 (0.00)	11.60	0.00	18.76	3.05 (3.05)	2.62 (0.00)	6.35	10.39
2	2.62 (0.00)	2.62 (0.00)	**11.75**	18.76	**2.63** (0.00)	2.62 (0.00)	11.53	0.24	18.26	3.42 (3.42)	2.62 (0.00)	6.68	9.74
2	*NO SUBSIDISATION only drug 2 subsidised in eqm.*				2.64 (0.00)	2.62 (0.00)	11.32	0.50	17.73	3.78 (3.78)	2.62 (0.00)	6.96	9.21

able 10.21: Comparison of systems with a difference in risk (inferior drug subsidised).[24]

For the cases where the costs of both firms are small reference pricing achieves the lowest roducer prices at the cost of a considerable surcharge for the consumption of the superior drug. his again comes at the cost of risking non-subsidisation in the case that the entrant has a high ost. Where the incumbent has marginal costs of zero there is a 16% chance (the probability that $_1 > 1.67$) that the entrant will prefer to remain unsubsidised charging over $3.50 for treatment hich must be borne totally by consumers.

Where the incumbent has moderate costs reference pricing again achieves generally lower rices. The producer price of the inferior drug is smaller under reference pricing while the uperior drug is marginally more expensive than under the modified JZ scheme. The chance of on-subsidisation falls to around 12% here.[25] The JZ scheme again provides greater consumer urplus to consumers at the expense of greater subsidy payments.

The case of a high cost incumbent is interesting. With higher costs the reaction function of he incumbent under reference pricing is sufficiently high to change the type of behaviour

[24] See Appendix 10.1 for full table.

[25] In this case a firm with marginal cost 1.75696 is indifferent to whether or not they are reference riced.

chibited. Instead of the incumbent choosing to undercut it now chooses to remain at the cisting reference price. The JZ variant continues to give a higher payoff to the higher quality ug to compensate them for their non-subsidised profits. This results in higher prices than ference pricing where the cost to the entrant is moderate and above but guarantees that eatment will remain available to consumers free of charge. For firms with costs greater than pproximately 1.96 subsidisation under reference pricing is not worthwhile when compared to ie alternative of charging a high price directly to consumers.

Again the inability of reference pricing to discriminate between high and low quality drugs ieans that subsidisation is not guaranteed, even where the targeted drug represents a great dvance to consumers. With a drug as effective as the entrant this leads to a 23% smaller onsumer surplus measure under reference pricing as opposed to the JZ scheme. Subsidies /ould have to increase to compensate for this consumer surplus and efficiency would be slightly nhanced (an average increase of $3.41 m on the nine cases considered) by a move to ubsidisation under a JZ framework. As the magnitude of average treatment cost is similar etween the schemes the JZ scheme is found to be superior since it provides higher consumer nd total surplus measures without wastefully transferring large subsidies to the drug companies.

Average decrease in subsidies (RP → JZ)	-$ 2.36 m (-25.93%)
Average decrease in CS (RP → JZ)	-$ 3.41 m (-23.02%)
Average total surplus - RP	$ 13.74 m
Average total surplus - JZ	$ 13.87 m
Average change in total surplus (RP → JZ)	$ 0.13 m

Table 10.22: Difference in risk ($\lambda = 1.00,\ \eta = 1.00$ previously subsidised)

/III. SUMMARY OF COMPARISONS

The cases considered above give a qualified approval to reference pricing over the nodified version of the Johnston and Zeckhauser scheme. This approval is based on a higher :fficiency measure in most of the addressed cases, including the three considered to be most ikely (the identically distributed and balanced asymmetry scenarios). As the JZ scheme guarantees subsidisation it is more predictable in its outcomes than reference pricing. Unfortunately for the JZ scheme the cost of this predictability is a delay in subsidisation which

ill often reduces both consumer and total surplus. In the less likely cases (where drugs that are ɔt the same or similar are listed together in a subgroup) the JZ scheme delivers subsidisation ithout promoting significantly higher prices. It may be possible that the JZ scheme could be ɜed in a limited form to provide subsidisation where reference pricing fails to provide the ɛcessary incentive to join the scheme. An alternative means to provide subsidisation may be a ıluable tool for Pharmac here. Note that firms with similar products would not have an ıcentive to falsely signal differentiated products as the returns accruing to such firms under the Z scheme are relatively low.

Efficiency considerations recommend reference pricing in cases where drugs are ıaracterised similarly. With such drugs, reference pricing leads to no price differentials and the rugs attain a relatively even share of the market. Here reference pricing results in zero ɔnsumer prices throughout the time period. The JZ scheme results in zero prices only from the me of subsidisation onwards. Pre-subsidisation, the JZ scheme results in high consumer prices ɔr the entrant and correspondingly lower consumer and total surplus measures. The JZ scheme romotes lower efficiency because of lower total surplus during the pre-subsidisation period. 'he cases of identically distributed drugs and a balanced asymmetry between drugs favour ɛference pricing for this reason.

Efficiency considerations recommend the JZ scheme in many of the remaining cases. Vhere there is a large difference in efficacy (for example $\lambda_1 = 1, \lambda_2 < 0.62$, where $\eta_i = 1$) and the ıferior firm attempts to join the scheme the benefits of the drug are often not enough to justify ıe marginal cost of treatment. Total surplus is often higher in the case where the ɔre-subsidisation price is charged rather than zero. Reference pricing, which immediately chieves a zero price for the entrant is therefore of a lower level of efficiency than the JZ variant. Vhere there is a difference in efficacy and the superior firm is the entrant there is no guarantee hat subsidisation will take place under reference pricing. Here there is a significant probability hat the entrant will choose not to be reference priced, resulting in a large drop in consumer urplus. Efficiency is higher under the JZ scheme which achieves subsidisation at a low price, ılbeit with a delay.

Where the case of a difference in risk is considered, efficiency favours the JZ scheme in the ɜase of a superior entrant. Here the problem referred to immediately above occurs again in that

; entrant may optimally choose not to accept subsidisation under reference pricing. This makes 'erence pricing far less expensive but causes a large drop in total surplus.

Where there is a difference in risk with entrant seeking listing alongside a superior ernative both schemes achieve subsidisation. Where the inferior firm has a low marginal cost chooses to price considerably below the pre-entry reference price. The relatively large nsumer price leads to far lower consumer surplus, although total surplus is higher under ference pricing. The superior efficiency under reference pricing is due both to higher consumer ices (which are more accurate signals of marginal cost) promoted, and the delay the JZ requires fore subsidisation occurs.

For a scheme to be judged superior overall it would have to promote either a moderately tter outcome in the cases where drugs were similar (which are the most likely scenarios) or it ould have to promote a very large increase in efficiency in some of the less likely cases. The ference pricing scheme satisfies the former of these criteria, while the JZ scheme fails to omote far higher efficiency in the less realistic cases in which it is superior.

These results may however depend on the values taken for different variables. The nsitivity of results to changes in these variables is assessed in the following section.

1. SENSITIVITY TESTS

The above results rely on several variables many of which have already been tested for ieir affect on results through the comparisons. Differences in efficacy, risk and costs are not nalysed because of their inclusion in this process. The following two sections consider changes o the results as a consequence of changes in the allowable time to subsidisation and the time ntil generic entry. Section 3 analyses the effect of adding a fixed charge to the model. This ixed charge would apply to all drugs under the JZ scheme and serve as a base to which positive rice differentials would be added under reference pricing. Tables for each of these cases are ncluded in Appendix 10.2.

(1) Sensitivity of results to the allowable time to subsidisation

The previous chapter showed how the JZ scheme defines the subsidy received by a firm as unction of the time at which subsidisation is accepted. Firms with low marginal costs are couraged to signal their true cost by means of decreasing premium on top of the payment pporting their pre-subsidisation profits. This premium decreases to zero at the maximum owable time to subsidisation. Two alternative cases are considered to the $t_{max} = 0.5$ years used ove: $t_{max} = 0.25$ and $t_{max} = 1.00$. It is expected that the more patient is the agency[26] the lower ll be the premium required for subsidisation within the time threshold.

The case of identical drugs where both firms have marginal cost equal to 1 is considered r the purpose of analysing the sensitivity of results to t_{max}. In the normal case[27] initial bsidisation occurs at time t = 0.2405 at a price of 2.6002. Prior to subsidisation the firm would ıve priced at 3.5722 in order to obtain maximum profits. A firm determines this pre-subsidised ice by trading off cost and benefits of moving from the non-subsidisation optimum. A higher e-subsidisation price increases the premium on offer to firms received once subsidised. lternatively the higher is the pre-subsidised price the lower will be profits before subsidisation ccurs and the lower will be the price that makes firm indifferent over whether it is subsidised.

Low cost firms are subsidised quickly under the JZ scheme and so obtain a relatively large emium. By pricing above their no-subsidisation optimum these firms can increase the size of ıe premium and attain higher profits. Firms with higher costs face a longer time unsubsidised ıd so receive a smaller premium. These firms find it optimal to price closer to their no-ıbsidisation optimum because the payoff to increasing their price is lower.[28] Firms with the ıaximum marginal cost possible never receive a premium and so choose to price at their no-ıbsidisation optimum.

Suppose that the time threshold for subsidisation (t^*) falls so that firms with positive costs xpect to be subsidised sooner. The benefits to pricing above the no-subsidisation optimum have ıcreased because the period over which the increased premium is enjoyed has grown. Firms

---

[26] And hence the longer the delay to subsidisation.

[27] $t^* = 0.50$

[28] The price referred to here is pre-subsidisation price.

th marginal costs less than the maximum will then price further away to their respective no-
)sidisation optimum, selecting a higher pre-subsidised price. Where the time threshold falls to
:5 initial subsidisation of a firm with $\lambda = 1.00$, $\eta = 1.00$ and marginal cost of 1 predictably occurs
)re quickly than where the time threshold is $t_{max} = 0.50$. Subsidisation is accepted at t = 0.1226
a higher price (2.6094) and is motivated by the greater pre-subsidised price of 3.5891. Note
it the shortening of the time threshold affects both reference pricing and the modified JZ
heme since both use the same value for initial subsidisation. With an entrant marketing an
dependent and identically distributed drug (denoted drug 1) the outcomes of the JZ scheme and
ference pricing are given below:

	Reference Pricing				JZ Variant					Only drug 2 subsidised			
x	p_1 (p_1^c)	p_2 (p_2^c)	subsidy ($m)	CS ($m)	p_1 (p_1^c)	p_2 (p_2^c)	subsidy ($m)	delay	CS ($m)	p_1 (p_1^c)	p_2 (p_2^c)	subsidy ($m)	CS ($m)
:5	**2.61** (0.00)	2.61 (0.00)	**10.15**	12.78	2.38 (0.00)	2.61 (0.00)	9.64	0.12	12.66	2.95 (2.95)	2.61 (0.00)	7.05	8.99
50	**2.60** (0.00)	2.60 (0.00)	**10.11**	12.78	2.37 (0.00)	2.60 (0.00)	9.54	0.24	12.56	2.95 (2.95)	2.60 (0.00)	7.03	8.99

able 10.23: Comparison of results with a shortening of the allowable time threshold.[29]

The results of each of these cases are similar as far as subsidies and consumer surplus are)ncerned; reference pricing promotes higher prices and subsidy payments than the modified JZ :heme. With a higher pre-entry reference price subsidy payments have increased under :ference pricing. Subsidy payments have increased under the JZ scheme due to slight increases ı price and a longer period over which subsidisation occurs. This second factor slightly closes ıe gap between the subsidy payments required under each scheme. Under the smaller threshold alue a comparison of total surplus still favours reference pricing over the JZ scheme as any elay harms efficiency here. The margin by which the efficiency measure favours reference ricing has fallen with the effect of shifting from the RP scheme to JZ being -$0.18 m for the $_{max}$ = 0.50 case but only -$0.09 for the smaller threshold.

The following diagrams show the effect of reducing the subsidisation threshold graphically. 'he diagram on the left is relevant to a firm with constant marginal costs of 1 under the JZ cheme since this firm would price at 3.4559 pre-subsidisation. The graph shows the prices)ffered to such a firm if it accepts subsidisation at time t where the time threshold is 0.25 years.

[29] See Appendix 10.1 for full table.

such a firm was to have accepted subsidisation at time zero it would be subsidised at a price of ›proximately 2.35, if it waited until t = 0.25 it would obtain a price of approximately 2.39. iven this function the firm chooses to accept subsidisation at time 0.1226 and receives a price ·2.3783.

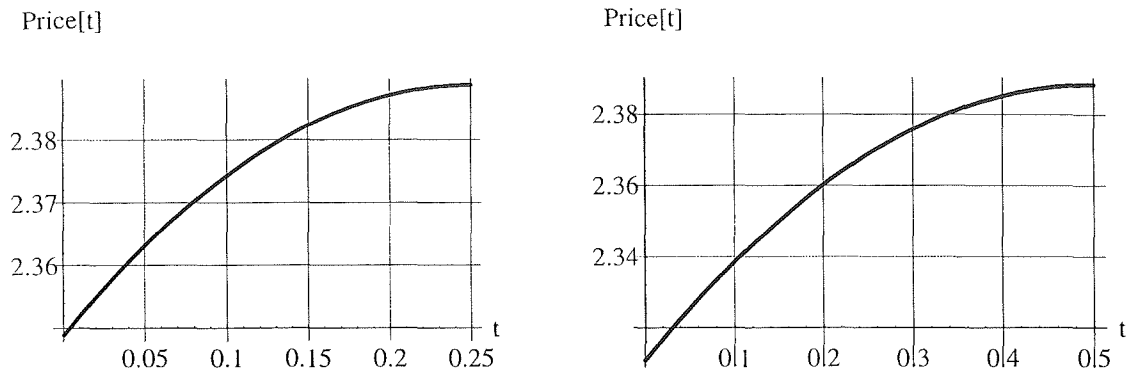


Figure 10.8: Price functions for time thresholds 0.25 and 0.5, respectively.

The diagram on the right displays the prices offered to the same firm where the time ıreshold is 0.50. The firm charges at 3.4353 before being subsidised and chooses when to :cept subsidisation given that the subsidy to a firm accepting subsidisation at time t is as shown n the second graph. The price at the end of the period is very close to the equivalent under the ›wer time threshold while price at time zero is approximately 2.31. Reducing the time to ubsidisation reduces the potential for the JZ scheme to restrict prices since the smaller the ıreshold is the closer are prices to the level required to make the maximum cost firm indifferent › whether subsidisation occurs.

For the case of a longer time to subsidisation the results found are still close to those in the ›riginal but, because of a longer delay to subsidisation, tend to favour the modified JZ scheme nore. With t_{max} = 1.00 initial subsidisation occurs at time 0.4641 and results in a price 2.5808. \ price of 3.5402 had been charged by the first firm before subsidisation.

	Reference Pricing				JZ Variant					Only drug 2 subsidised			
max	p_1 (p_1^c)	p_2 (p_2^c)	subsidy ($m)	CS ($m)	p_1 (p_1^c)	p_2 (p_2^c)	subsidy ($m)	delay	CS ($m)	p_1 (p_1^c)	p_2 (p_2^c)	subsidy ($m)	CS ($m)
.00	**2.58** (0.00)	2.58 (0.00)	**10.04**	12.78	2.34 (0.00)	2.58 (0.00)	9.33	0.46	12.36	2.95 (2.95)	2.58 (0.00)	6.98	8.99
.50	**2.60** (0.00)	2.60 (0.00)	**10.11**	12.78	2.37 (0.00)	2.60 (0.00)	9.54	0.24	12.56	2.95 (2.95)	2.60 (0.00)	7.03	8.99

Table 10.24: Comparison of results with a lengthening of the allowable time threshold.[30]

[30] See Appendix 10.1 for full table.

Again the general results found earlier hold here also. It appears that while changing the ximum allowable time to subsidisation does affect the level of prices it does not change the iparative standings of RP and the JZ variant significantly as far as the general results in es, subsidies and consumer surplus obtained. Under a total surplus comparison however the between reference pricing and the JZ scheme has grown from \$0.18 m (t_{max}= 0.50) to 35 m (t_{max} = 1). Given these, and even higher thresholds the findings of this thesis in favour eference pricing become stronger still. The diagram corresponding to the price function the n faces under a threshold of t_{max} = 1 is given below:

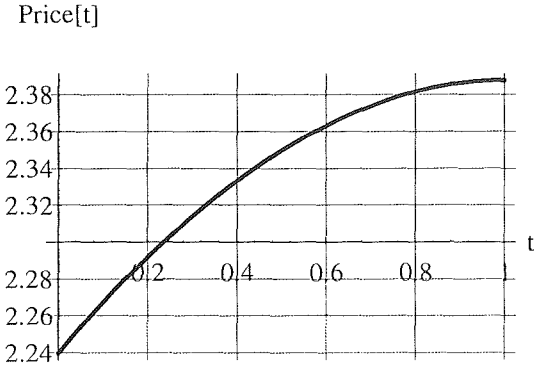


Figure 10.9: Price functions for time threshold 1.00.

The prices available to the firm on acceptance of subsidisation vary greatly with respect to time threshold. This diagram strengthens the argument above that the smaller is the threshold flatter is the curve representing the prices on offer to a firm. The flatter is this curve the aller is the advantage gained by using a scheme that discriminates on price over a scheme that mpensates all firms at the level perfectly compensating a firm with c = 2. The general results likely to be consistent between different cases relieving concern over the sensitivity of results the time threshold.

(2) Sensitivity of results to the time to generic entry

The comparison above has used a time to generic entry equal to the effective patent life of a ug but it is acknowledged that this may be inaccurate for one of two reasons. There may be a lay either between the registration of a drug and any application to Pharmac or a delay once ch an application has been lodged while firms await a response from Pharmac. Generic drugs ay either not be available at the time of patent expiration or they may face significant barriers to

ry. Woodfield, Fountain and Borren make reference to an informal policy of Pharmac to uire successive generic entrants to cut prices by 30%, 20%, and 10% of the currently reference ced product. It was argued that this could represent a significant deterrent for generic entry.[31]

Of these factors the latter is judged to be significant to only generics while the former is ely to apply to both innovators and generic manufacturers. Delays in introduction applying to th innovative drugs and generics will cancel out and so are ignored here. In order to be safe a atively long delay is assumed for generic entry into the market for the purposes of this nsitivity test so that the total time innovative drugs face they expect before generic entry is 8.00 ars. This is composed of the 5.98 years that has been estimated for effective patent life under ew Zealand patent law and a delay to generic entry of just over two years. As before the case of entically distributed drugs is assessed where the time threshold is 0.5 and marginal costs are 1.

ne	Reference Pricing				JZ Variant					Only drug 2 subsidised			
entry	p_1 (p_1^c)	p_2 (p_2^c)	subsidy ($m)	CS ($m)	p_1 (p_1^c)	p_2 (p_2^c)	subsidy ($m)	delay	CS ($m)	p_1 (p_1^c)	p_2 (p_2^c)	subsidy ($m)	CS ($m)
)0	**2.60** (0.00)	2.60 (0.00)	**12.40**	15.63	2.37 (0.00)	2.60 (0.00)	11.71	0.24	15.41	2.95 (2.95)	2.60 (0.00)	8.61	11.00
)8	**2.60** (0.00)	2.60 (0.00)	**10.11**	12.78	2.37 (0.00)	2.60 (0.00)	9.54	0.24	12.56	2.95 (2.95)	2.60 (0.00)	7.03	8.99

able 10.25: Comparison of results with an extension of patent protection.[32]

For the case where $T = 8.00$ very little changes as far as the results obtained are concerned. he subsidies required and CS resulting from each alternative inevitably rise with the expansion f the time frame. What has not changed is that reference pricing still results in larger prices and ubsidy costs for both firms. Prices have risen slightly[33] because the relative length of time ıreshold to the total time period lengthens as a result of the change. The change is minor owever since profits are discounted by firms when making decisions.[34] Without changes in the elative sizes of variables between schemes very little has changed, suggesting that the

[31] Woodfield, A. and others (1997) p.150.

[32] See Appendix 10.1 for full table.

[33] As an example the price of firm 1 under the JZ variant rose by 0.004.

[34] The value of \$1 given through the additional period is only $\int_{5.98}^{8.00} e^{-0.1t} dt = 1.0058$. The total value of 1 profit throughout the interval does not change greatly as a result of the lengthening and so neither do ptimal choices.

mparisons above are not particularly sensitive to a lengthening of the time period. A ortening of the time period is unlikely unless the effective patent life of a drug falls further and is not considered here.

In an efficiency comparison reference pricing was found to be $0.18 m superior to the JZ heme for the case where $T = 5.98$. Where the larger time to generic entry is considered the fference is close to this level while the overall size of total surplus has increased, rendering the fference less significant. It is expected that this difference will remain under larger time ɔrizons as the JZ scheme still requires a delay for signalling purposes. The findings of this esis should then persist under changes to the time to generic entry.

(3) Sensitivity of results to a positive fixed charge

Both the JZ and RP schemes allow for the levying of a fixed charge to consumers. In the ase of the JZ scheme consumers face this charge on every treatment option while under ɛference pricing consumers face this charge plus any positive price differential. Previously a xed charge of zero has been used for simplicity reasons. The sensitivity of the results to the nplementation of a positive charge is expected to be very low given that this charge applies qually to both schemes and to all drugs in the subgroup. A fixed charge of 0.50 has been pplied to all patients for the purpose of this analysis which addresses the case of two identically istributed drugs with qualities distributed according to $\lambda = 1.00$, $\eta = 1.00$ and marginal costs of .[35] With the fixed charge of $k = 0.50$ initial subsidisation involves higher prices with the ncumbent accepting subsidisation at time $t = 0.2405$ and receiving a subsidy-inclusive price of ⁚.6412.

[35] In reality different groups of people are charged different amounts for the same medicine. The ıctual price paid may depends the income, age, occupation and prior illnesses of a patient. For example, ow income patients and students may use community service cards to obtain cheaper (or free) treatment. Γhese differences between individuals are ignored in the simple test above which attempts only to see ɛffects of imposing a positive charge. If the relative standings of schemes do not change greatly in the ɜensitivity test then the results are likely to hold for all patients of similar income, age etc. If standings ıold across all the different types of consumers the results, being an aggregation of each of the individual ɔases, should hold.

	Reference Pricing				JZ Variant					Only drug 2 subsidised			
	p_1 (p_1^c)	p_2 (p_2^c)	subsidy ($m)	CS ($m)	p_1 (p_1^c)	p_2 (p_2^c)	subsidy ($m)	delay	CS ($m)	p_1 (p_1^c)	p_2 (p_2^c)	subsidy ($m)	CS ($m)
0.50	**2.64** (0.50)	2.64 (0.50)	**8.04**	10.86	2.42 (0.50)	2.64 (0.50)	7.53	0.24	10.68	2.95 (2.95)	2.64 (0.50)	5.38	7.68
0.00	**2.60** (0.00)	2.60 (0.00)	**10.11**	12.78	2.37 (0.00)	2.60 (0.00)	9.54	0.24	12.56	2.95 (2.95)	2.60 (0.00)	7.03	8.99

ble 10.26: Comparison of results with the addition of a fixed charge.[36]

With a fixed charge quantity falls and price rises but not by the full value of the charge. bsidy payments have fallen because of lower per-unit subsidies and quantities. The relative sitions of the three schemes have stayed constant with reference pricing promoting higher ices and increased subsidy costs to the JZ alternative. Both the RP and modified JZ schemes e superior to leaving the entrant's drug unsubsidised on the basis of consumer surplus while th are correspondingly more expensive.

Total surplus in the benchmark case found that reference pricing was $0.18 m superior to e JZ scheme. With the addition of a fixed charge this figure falls to $0.15 m suggesting corporation of a fixed charge would have enhanced the strength of the JZ scheme in the mparison to reference pricing above. The effects of larger fixed charges are unknown and may esent an avenue for further research.

In summary the results obtained above appear to be stable with respect to the factors of the aximum time to subsidisation, the value of the fixed charge placed on drugs and the time that novators enjoy freedom from generic competition.

[36] See Appendix 10.1 for full table.

MARGINAL COST PRICING

Under a modified form of the JZ scheme it is possible to charge consumers the marginal st of their treatment. A parallel scheme under reference pricing would see firms charge at arginal cost plus any positive price differential. This modified reference pricing scheme is owever not possible given the restraints that Pharmac places on entry under reference pricing. Pharmac was to release these restraints then the pharmaceutical bill would rise sharply as ference pricing in an unrestricted form is unable to keep prices low.

The basis of the JZ scheme was a signalling equilibrium where different firms select fferent points at which to enter and gain different payments in equilibrium. These payments creased over time and were orientated in such a way as to make it worthwhile for firms to edibly signal their true cost. It is the necessity that these subsidies increase that prevents a gnalling equilibrium in price under reference pricing.[37] The scenarios above suggest that firms cepting subsidisation under reference pricing typically do so at the pre-existing reference price. all firms choose to price at the same level there appears to be no way for Pharmac to ifferentiate between firms of different costs. Without the ability to identify the marginal cost of firm a scheme of marginal cost pricing is impossible. Where firms have positive fixed costs ie problem of such pooling equilibria may prevent the use of Ramsey pricing which relies on an gency knowing the both the fixed and marginal costs of the firm.[38]

The modified JZ scheme identified previously gives the subsidising agency more options vith respect to policy decisions. While such options are not essential for an agency such as harmac they may prove valuable. The ability to use a cheaper scheme in areas where ubsidisation is currently considered marginal may enhance the chance of drugs being available o consumers at low cost.

---

[37] Signalling equilibria where other variables are used are likely to be logistically difficult but may still be possible.

[38] Ramsey pricing is a two part scheme involving a fixed fee and price per unit. The price per unit s equal to marginal cost of the firm. The fixed fee is specific to individuals and is inversely proportional o the buyer's elasticity of demand.

.I. PATENT INTEGRITY

The ability of firms to make payments to parent companies is a vital link in the process of ncouraging research and development in the pharmaceutical industry. New Zealand's scheme f reference pricing has faced criticism for not providing adequate returns to pharmaceutical ıdustry. Danzon (1997) specifically identifies New Zealand as a small country not contributing ɔ research and development in the following quote:[39]

> The low ratio of marginal cost to sunk, joint costs gives any powerful drug purchaser an incentive to try to drive prices down to the marginal cost of serving their patient population, leaving others to pay the joint costs of R&D. Small countries such as New Zealand can pursue this strategy with a negligible effect on global incentives for drug innovation as long as markets remain separate. The effects of these strategies expand, however, and affect consumers worldwide once spillovers become common and markets are no longer separable because of parallel trade and regulation based on international price comparisons.

In addition to the arguments put forward above a scheme promoting insufficient returns vill also spread if seen to be effective. While such a scheme may be relatively harmless if ɔursued in one or two small countries only it becomes dangerous to patent integrity if appreciable ɔortions of the worldwide pharmaceutical market adopt it.

The following section addresses the profits made by each firm and attempts to assess the ɛffects of subsidisation on the ability of firms to make research and development contributions to parent companies. This analysis cannot seek to state whether either the JZ or reference pricing schemes would allow for a reasonable return to pharmaceuticals in a real world situation since this depends largely on the length of patent protection. This section compares each scheme to an unregulated duopoly and can only assess whether, given a sufficient patent length, a scheme provides for sufficient profits to protect the integrity of the R&D process.

Part of the rationale for not using option four of the original JZ scheme for the template of the modified version was concern over the low level of profit accruing to firms. For the patent system to retain integrity there must be parity between the profits achievable under the subsidisation scheme and the free market. The following tables examine the outcomes expected

---

[39] Danzon, P.M. (1997) *Pharmaceutical Price Regulation: National Policies Vs Global Interests.* Washington, AEI Press. p.25

or each case under a unregulated duopoly as well as the modified JZ and reference pricing chemes.

(1) Identically distributed drugs

Entrant: $\lambda = 1.00, \eta = 1.00$ Incumbent: $\lambda = 1.00, \eta = 1.00$

	Unregulated duopoly			JZ Variant			Reference pricing		
	$c_2 = 0$	$c_2 = 1$	$c_2 = 2$	$c_2 = 0$	$c_2 = 1$	$c_2 = 2$	$c_2 = 0$	$c_2 = 1$	$c_2 = 2$
$c_1 = 0$	3.49	3.84	4.12	*4.50*	*4.50*	*4.50*	*4.97*	*5.06*	*5.09*
	3.49	2.26	1.28	*4.97*	*3.11*	1.20	*4.97*	*3.11*	1.20
$c_1 = 1$	2.26	2.45	2.69	*2.59*	*2.59*	2.59	*3.02*	*3.11*	*3.15*
	3.84	2.45	1.39	*5.08*	*3.18*	**1.23**	*4.97*	*3.11*	**1.20**
$c_1 = 2$	1.28	1.39	1.52	**0.76**	**0.76**	**0.76**	**1.08**	**1.17**	**1.20**
	4.12	2.69	1.52	*5.20*	*3.26*	**1.26**	*4.97*	*3.11*	**1.20**

Table 10.27: Profits to firms with identically distributed drugs.[40]

Table 10.31 displays the profits accruing to firms where both firms have identically distributed drugs characterised by $\lambda = 1.00, \eta = 1.00$. Under an unregulated duopoly the average profit for a firm in the nine cases displayed is \$2.56 m. For both the JZ variant and reference pricing to maintain the integrity of the patent system each must contribute at least this amount on average. In the above table where the profits to a firm are more than \$0.10 m lower than the profits under the unregulated duopoly position they are displayed in bold type. Where the profits are more than \$0.10 m higher than expected without any subsidisation they are displayed in an italic font. Through this simple device it is hoped that a graphic representation of the behaviour of each scheme with respect to profits can be used to aid the summary of results. This convention is continued through to Table 10.33.

The JZ scheme favours the incumbent firm as this firm receives a large subsidy than if positions with the entrant were reversed since it makes lower unsubsidised profits when facing competition. Under the JZ scheme high cost firms are unlikely to make the profits they would have had the market been unregulated but this loss is outweighed by the higher profits made elsewhere. On an average of the nine cases considered the entrant makes \$ 2.62 m while the incumbent gains \$3.17 m, both of which are in excess of the \$ 2.65 m that would have been made in the absence of regulation.

[40] In \$m, drug 1 is assumed to be the entrant's product. Profits in each cell appear as $\binom{\pi_1}{\pi_2}$.

Reference pricing also provides adequate returns to firms. Under reference pricing both the entrant and incumbent make \$3.09 m. The cases above for reference pricing are not generally symmetrical in the sense that the profit accruing to the entrant where c_1=0 and c_2=2 does not equal the profit to the incumbent where c_1=2 and c_2=0. For profits to be symmetric in the above sense would require that the pre-entry reference price in each case is identical which in turn requires firms to have identical costs. As with the JZ case high cost firms are typically under-funded in the sense that their profits are less than that expected under an unregulated duopoly. The reference pricing scheme does provide for slightly smaller profits for the incumbent firm than the JZ scheme but larger profits for the entrant.

(2) Balanced asymmetry

Entrant: $\lambda = 0.90, \eta = 1.00$ Incumbent: $\lambda = 0.85, \eta = 1.10$

	Unregulated duopoly			JZ Variant			Reference pricing		
	$c_2 = 0$	$c_2 = 1$	$c_2 = 2$	$c_2 = 0$	$c_2 = 1$	$c_2 = 2$	$c_2 = 0$	$c_2 = 1$	$c_2 = 2$
$c_1 = 0$	3.00	3.29	3.51	*4.04*	*4.04*	*4.04*	*4.27*	*4.36*	*4.39*
	2.85	1.69	0.82	*4.59*	*2.72*	0.80	*4.59*	*2.72*	0.80
$c_1 = 1$	1.81	2.00	2.17	*2.25*	*2.25*	2.25	*2.44*	*2.53*	*2.57*
	3.13	1.84	0.89	*4.68*	*2.78*	0.82	*4.59*	*2.72*	0.80
$c_1 = 2$	0.93	1.02	1.12	**0.54**	**0.54**	**0.54**	**0.62**	**0.71**	**0.74**
	3.37	2.02	0.97	*4.77*	*2.83*	**0.83**	*4.59*	2.72	**0.80**

Table 10.28: Profits: balanced asymmetry ($\lambda = 0.85, \eta = 1.10$ incumbent).[41]

In the case of a balanced asymmetry the firm with $\lambda = 0.85, \eta = 1.10$ typically makes profits of around \$1.95 m under the unregulated position while a firm with $\lambda = 0.90, \eta = 1.00$ gains \$2.09 m. Both the JZ and reference pricing schemes allow for profits greater than these amounts. Where the entrant drug is characterised by $\lambda = 0.90, \eta = 1.00$ the JZ scheme promotes average profits of \$2.28 m while the RP scheme provides for profits of \$2.51 m. Under each of these schemes lower cost firms predictably make higher profits these averages. The incumbent firm here makes profits of \$2.76 m (JZ) and \$2.70 m (RP) both of which are higher than the profits achieved under an unregulated duopoly.

[41] In \$m, drug 1 is assumed to be the entrant's product. Profits in each cell appear as $\left(\frac{\pi_1}{\pi_2}\right)$.

ıtrant: $\lambda = 0.85, \eta = 1.10$ Incumbent: $\lambda = 0.90, \eta = 1.00$

	Unregulated duopoly			JZ Variant			Reference pricing		
	$c_2 = 0$	$c_2 = 1$	$c_2 = 2$	$c_2 = 0$	$c_2 = 1$	$c_2 = 2$	$c_2 = 0$	$c_2 = 1$	$c_2 = 2$
= 0	2.85	3.13	3.37	*4.30*	*4.30*	*4.30*	*4.71*	*4.80*	*4.84*
	3.00	1.81	0.93	*4.38*	*2.64*	0.85	*4.38*	*2.64*	0.85
= 1	1.69	1.84	2.02	*2.38*	*2.38*	*2.38*	*2.75*	*2.84*	*2.88*
	3.29	2.00	1.02	*4.48*	*2.70*	**0.87**	*4.38*	*2.64*	**0.85**
= 2	0.82	0.89	0.97	**0.53**	**0.53**	**0.53**	0.79	0.88	**0.92**
	3.51	2.17	1.12	*4.58*	*2.77*	**0.89**	*4.38*	*2.64*	**0.85**

'able 10.29: Profits: balanced asymmetry ($\lambda = 0.90, \eta = 1.00$ incumbent).[42]

Where the drug with the distribution characterised by $\lambda = 0.90, \eta = 1.00$ is the incumbent both :hemes give (on average) greater profits to both schemes than enjoyed under the unregulated ase. The incumbent can expect to receive \$2.95 m under the JZ scheme and \$2.62 m under the .P scheme while only \$2.09 m is expected under an unregulated duopoly. The entrant receives 2.40 m under the JZ scheme and \$2.82 m under reference pricing, up from \$1.95 under an nregulated duopoly.

It is expected that in comparisons over the entire range of costs both schemes give ufficient returns to firms to allow them to make at least the R&D contributions made were no ubsidy scheme in place.

(3) Difference in efficacy

ntrant: $\lambda = 0.50, \eta = 1.00$ Incumbent: $\lambda = 1.00, \eta = 1.00$

	Unregulated duopoly			JZ Variant			Reference pricing		
	$c_2 = 0$	$c_2 = 1$	$c_2 = 2$	$c_2 = 0$	$c_2 = 1$	$c_2 = 2$	$c_2 = 0$	$c_2 = 1$	$c_2 = 2$
ı = 0	0.90	0.97	1.06	*2.74*	*2.74*	*2.74*	*3.63*	*3.70*	*3.72*
	4.23	2.78	1.59	*5.86*	*3.67*	*2.29*	*5.86*	*3.67*	**1.42**
ı = 1	0.32	0.35	0.38	*1.35*	*1.35*	*1.35*	*2.21*	*2.28*	2.30
	4.40	2.92	1.70	*5.93*	*3.71*	**1.42**	*5.86*	*3.67*	**1.42**
ı = 2	0.04	0.04	0.04	0.03	0.03	0.03	*0.79*	*0.85*	*0.88*
	4.48	2.99	1.75	*6.00*	*3.76*	**1.45**	*5.86*	*3.67*	**1.42**

Table 10.30: Profits: difference in efficacy ($\lambda = 1.00, \eta = 1.00$ incumbent).[43]

[42] In \$m, drug 1 is assumed to be the entrant's product. Profits in each cell appear as $\binom{\pi_1}{\pi_2}$.

[43] In \$m, drug 1 is assumed to be the entrant's product. Profits in each cell appear as $\binom{\pi_1}{\pi_2}$.

'his case gives excess profits to both firms in the vast majority of cases. Only where the ıcumbent has a high cost is there potential for firms to be given less than had no subsidisation :heme been implemented. The incumbent here makes profits of $2.98 m in an unregulated uopoly but $3.69 m and $3.65 m under the JZ and reference pricing schemes respectively. The ntrant makes far greater profits under the subsidisation schemes than an unregulated duopoly: 1.37 m (JZ) and $2.26 m (RP) as compared to $0.46 m in the absence of subsidisation. Both irms benefit from subsidisation in almost all cases.

ntrant: $\lambda = 1.00, \eta = 1.00$ Incumbent: $\lambda = 0.50, \eta = 1.00$

	Unregulated duopoly			JZ Variant			Reference pricing		
	$c_2 = 0$	$c_2 = 1$	$c_2 = 2$	$c_2 = 0$	$c_2 = 1$	$c_2 = 2$	$c_2 = 0$	$c_2 = 1$	$c_2 = 2$
$_1 = 0$	4.23	4.40	4.48	*5.16*	*5.16*	*5.16*	*4.45*	*4.60*	*4.66*
	0.90	0.32	0.04	*2.76*	*1.43*	0.04	*2.76*	*1.43*	0.04
$_1 = 1$	2.78	2.92	2.99	*2.91*	2.91	2.91	**2.29**	**2.30**	**2.37**
	0.97	0.35	0.04	*2.84*	*1.47*	0.05	*1.42*	*1.43*	0.04
$_1 = 2$	1.59	1.70	1.75	**0.76**	**0.76**	**0.76**	**0.76**	**0.76**	**0.76**
	1.06	0.38	0.04	*2.92*	*1.51*	0.05	4.25	1.43	0.07

Table 10.31: Profits: difference in efficacy ($\lambda = 0.50, \eta = 1.00$ incumbent).[44]

Where the superior drug seeks to enter the market there are problems regarding the level of ubsidisation of this firm. Under the JZ variant the firm makes $2.94 m as opposed to $2.98 m vhen all firms are unsubsidised. This is a relatively small drop in profits (especially when :ompared to the increases in profits from JZ subsidisation earlier) although it does point to the)ossibility of serious problems should the difference in efficacy be any greater. The RP scheme s problematic in this case. The level of subsidisation is defined by the pre-entry reference price)f the incumbent. Where the incumbent is markedly inferior to the entrant the reference may not ıllow the entrant to make sufficient profits. Subsidisation is accepted by the entrant for the first wo cases but in the third ($c_2 = 2$) the offer of subsidisation is declined in favour of the firm 'etaining the ability to price above the reference price. Here the entrant makes only $2.53 m as)pposed to the $2.94 m required if reference pricing could be said to provide for adequate ;ubsidisation.

[44] In $m, drug 1 is assumed to be the entrant's product. Profits in each cell appear as $\binom{\pi_1}{\pi_2}$. With a ıigh cost entrant reference pricing is declined by the entrant who chooses to remain unsubsidised.

In each of the cases in Table 10.31 the incumbent is provided with at least as much profit that achievable under the unregulated duopoly. The $0.46 m made without subsidisation is 'arfed by the $1.45 m possible under the JZ scheme and the $1.58 m available under reference cing.

In general this case points to a serious problem with reference pricing that has been ɔntified earlier. Reference pricing gives no consideration to the quality of a drug so that a perior entrant may find that the subsidisation on offer is insufficient to prompt participation in ɔ scheme. Even where subsidisation is accepted reference pricing will not always give equate profits to firms at moderate levels of cost.

(4) Difference in risk

trant: $\lambda = 1.00, \eta = 1.00$ Incumbent: $\lambda = 1.00, \eta = 5.00$

	Unregulated duopoly			JZ Variant			Reference pricing		
	$c_2 = 0$	$c_2 = 1$	$c_2 = 2$	$c_2 = 0$	$c_2 = 1$	$c_2 = 2$	$c_2 = 0$	$c_2 = 1$	$c_2 = 2$
= 0	2.81	3.25	3.66	**1.46**	**1.46**	**1.46**	*3.19*	3.23	**3.24**
	8.56	6.16	3.94	*12.12*	*8.48*	*4.78*	*9.95*	*6.95*	3.91
= 1	1.61	1.97	2.30	**0.73**	**0.73**	**0.73**	*1.92*	1.95	**1.89**
	9.32	6.70	4.28	*12.25*	*8.57*	*4.82*	*10.85*	*7.57*	4.31
= 2	0.72	0.97	1.22	**0.03**	**0.03**	**0.03**	*0.94*	0.96	**0.97**
	10.18	7.31	4.67	*12.37*	*8.65*	*4.87*	*11.86*	*8.28*	4.66

able 10.32: Profits: difference in risk ($\lambda = 1.00, \eta = 5.00$ incumbent).[45]

Here the JZ scheme fails to give the requisite return to the entrant in any of the nine cases ɔnsidered. Without the ability to impose a positive price on its opposition the entrant makes ɔxt to no profits when unsubsidised which severely affects the profits it makes in equilibrium. he JZ scheme on promotes average profits of only $0.74 m to the entrant compared to the 2.06 m available to the firm on average had no subsidisation scheme been implemented. eference pricing also fails to allow the firm to make its required profits, the average of $2.03 m ılling slightly short of the unsubsidised level. The incumbent in each case is well provided for ɔceiving $8.54 m under the JZ scheme and $7.59 m under reference pricing compared with a gure of $6.79 m under an unregulated duopoly.

[45] In $m, drug 1 is assumed to be the entrant's product. Profits in each cell appear as $\binom{\pi_1}{\pi_2}$.

ıtrant: $\lambda = 1.00, \eta = 5.00$ Incumbent: $\lambda = 1.00, \eta = 1.00$

	Unregulated duopoly			JZ Variant			Reference pricing		
	$c_2 = 0$	$c_2 = 1$	$c_2 = 2$	$c_2 = 0$	$c_2 = 1$	$c_2 = 2$	$c_2 = 0$	$c_2 = 1$	$c_2 = 2$
= 0	8.56	9.32	10.18	*9.64*	*9.64*	*9.64*	**8.32**	**9.21**	**9.80**
	2.81	1.61	0.72	**1.91**	**1.20**	**0.46**	**2.29**	**1.26**	**0.46**
= 1	6.16	6.70	7.31	**5.96**	**5.96**	**5.96**	**5.06**	**5.67**	**6.05**
	3.25	1.97	0.97	**2.17**	**1.36**	**0.53**	**2.29**	**1.26**	**0.46**
= 2	3.94	4.28	4.67	**2.41**	**2.41**	**2.41**	**2.41**	**2.41**	**2.41**
	3.66	2.30	1.22	**2.44**	**1.53**	**0.59**	*6.79*	*4.25*	*1.64*

able 10.33: Profits: difference in risk ($\lambda = 1.00, \eta = 1.00$ incumbent).[46]

In the final case neither firm makes the profits it would have made were no subsidisation ffered. The entrant receives on average profits of only \$6.08 m under the JZ scheme and 5.70 m under reference pricing compared with the \$6.79 m it would have made under an nregulated duopoly. The incumbent also receives too little by way of profit from the JZ scheme 1.35 m (as opposed to \$2.06 m). Under reference pricing the entrant receives on average 2.30 m because of the non-subsidisation of high cost incumbents under reference pricing. In eneral both schemes would suggest that with differences as extreme as those in the case of an symmetry in risk above it is prudent to list both drugs in separate therapeutic subgroups in order ɔ maintain the integrity of the patent scheme. That this will occur is not clear given the subsidy avings available to agencies and may well be a cause of concern under any subsidisation cheme.

ΧII. RAMSEY PRICING

Posner (1992) defines Ramsey pricing as follows:[47]

> Ramsey pricing - if one ignores the formidable information costs entailed by efforts to measure elasticities and to prevent arbitrage - is the following. As in two-part pricing, every buyer pays and entry fee to cover fixed costs, but the fee varies inversely with the buyer's elasticity of demand - and the truly marginal buyer pays no entry fee. In addition to the entry fee each buyer pays the marginal cost of each unit that he buys. Given perfect information,

[46] In \$m, drug 1 is assumed to be the entrant's product. Profits in each cell appear as $\binom{\pi_1}{\pi_2}$. With a ıigh cost entrant reference pricing is declined by the entrant who chooses to remain unsubsidised.

[47] Posner, R.A. (1992) *The Economic Analysis of Law*. Boston, Little, Brown and Company. 4th ɔdition. pp.354-355.

output will be carried to the point where marginal cost intersects demand, yet without imposing a deficit on the regulated firm or a tax on non-users of the regulated service.

Posner describes the two part form of Ramsey pricing. Alternative forms of Ramsey ;icing exist that see different individuals purchasing goods at different rates according to the ıverse of their price elasticity of demand. The analysis below concentrates on the two part form f Ramsey pricing. This is not significant given the problems of applying Ramsey pricing here.

Ramsey pricing is unlikely to be an optimal arrangement in the market for pharmaceuticals. uppose that the subsidising agency does not know the individual specific side effect that a atient faces but still has perfect information over the costs of each firm. They will have to either ay exorbitant amounts to ascertain this figure or act only on the basis of the information by atients. If the agency decides to pursue the former they can obtain the true effect that the :lected drug has on a patient.

If the agency does not know the individual specific side effect a patient faces it acts from ıe only piece of information it has - that the patient actually used the drug in treatment. All atients using a particular drug are perceived identically by the agency and therefore must be ·eated identically. Two part pricing results with marginal cost charged on a per-unit basis and a ıxed charge of F/μ.[48] Patients indifferent over treatment at marginal cost will find it optimal ot to consume given the additional charge F/μ levied upon them. Ramsey price is distortionary ere and so loses its optimality. The JZ scheme of Chapter 7 (marginal cost pricing) is not istortionary although it will be more expensive to the government since it is not self-financing.[49]

Let us now consider the case where the individual specific side effect is known. Recall that he quantity of a drug taken is not a choice over a continuous range of values but rather is a ›inary choice. Quantity is choice between the values 0 (connotes no treatment) and 1 (implies ull treatment). This is not a particularly challenging assumption but causes major problems in he application of Ramsey pricing. For a patient facing quality φ_i:

---

[48] Where F is the fixed cost and μ is the quantity of the drug.

[49] Recall that the version of the JZ scheme in Chapter 7 was based on perfect information and so :ncompassed no delay.

$$q_i = \begin{cases} 0 & \text{if} \quad \varphi_i < \frac{p_i}{L} \\ 1 & \text{if} \quad \varphi_i \geq \frac{p_i}{L} \end{cases}$$

he derivative of the demand function is:

$$\frac{dq_i}{dp_i} = \begin{cases} 0 & \text{if} \quad p_i > L\varphi_i \\ -\infty & \text{if} \quad p_i = L\varphi_i \\ 0 & \text{if} \quad p_i < L\varphi_i \end{cases}$$

ıd the elasticity of demand is:

$$\varepsilon = \frac{dq_i}{dp_i}\frac{p_i}{q_i} = \begin{cases} \text{undefined} & \text{if} \quad L\varphi_i < p_i \\ -\infty & \text{if} \quad L\varphi_i = p_i \\ 0 & \text{if} \quad L\varphi_i > p_i. \end{cases}$$

Under Ramsey pricing patients who do not purchase the drug ($L\varphi_i < p_i = c_i$) and patients ho are indifferent towards the purchase of the drug ($L\varphi_i = p_i = c_i$) pay nothing. All fixed costs re paid by those who find purchasing the drug strictly better than not doing so. Elasticities are qual for all consumers with $\varphi_i > \frac{p_i}{L}$ so the fixed fee will be charged equally across all these atients.[50] Where fixed costs are positive some patients will decide not to undergo treatment ven though the net benefit of it is positive.[51] As in the case where no individual specific side ffects are known Ramsey pricing is less efficient than the marginal cost pricing JZ scheme of hapter 7.[52]

Ramsey pricing does not discriminate well between patients with different valuations in the ase where quantity is a binary choice. A scheme of Ramsey pricing cannot be recommended for

---

[50] The problem of the elasticity of demand being zero (the inverse of this is infinite) is ignored.

[51] Assume that Ramsey pricing is non-distortionary. That is, assume all patients with $\varphi_i > \frac{c_i}{L}$ ptimally choose treatment. Here the fixed costs of F are shared amongst the proportion μ of patients vho take the treatment. $\forall \ \varphi \in \left(\frac{c_i}{L}, \frac{c_i + F/\mu}{L}\right)$ treatment is therefore optimal. The gain in utility from reatment for these patients is negative and so we have a contradiction. Ramsey pricing is therefore listortionary in the case where utilities are known.

$$\left.\begin{aligned} L\varphi - (c_i + F/\mu) &< L\frac{c_i + F/\mu}{L} - (c_i + F/\mu) \\ &= (c_i + F/\mu) - (c_i + F/\mu) \\ &= 0 \end{aligned}\right).$$

[52] Where distortions are ignored. Without an adequate measure of the marginal deadweight loss of axation there is little that can be done to estimate the effects of a distortion.

.e in the case of pharmaceuticals if doubt remains over the way patients select treatment. While is acknowledged that the assumption that quantity is a binary choice is an assumption and not ct it appears plausible enough to seriously limit the chances of a successful Ramsey pricing :heme. Where quantity is a binary choice (as above) Ramsey pricing is equivalent to average)st pricing as consumers face only a choice between the options: pay no fixed charge, pay the xed charge but do not pay for treatment, or pay the fixed charge and for treatment. Of these the :cond option is trivially inferior. The choice becomes take no treatment or pay the marginal)st of treatment plus the average fixed cost of those accepting treatment. The "marginal cost of eatment plus the average fixed cost of those accepting treatment" is simply average cost and the ıtcome of Ramsey pricing simply represented by the same total payments and quantities as a :gulation setting price to average cost.

Where costs must be discovered Ramsey pricing imposes a far larger informational burden ıan either reference pricing or the JZ scheme. Not only must marginal costs be known but fixed osts also. As shown in Chapter 9 prices can be used to signal marginal cost but there appear to e few avenues for firms to signal fixed costs.

The alternative form of Ramsey pricing faces the same problems as given above. If all atients taking treatment have the same elasticity of demand they must be treated identically. Vhere the price to each patient is defined by this elasticity all prices must be identical. Average ost pricing results if fixed costs are met.

XIII. A DISCUSSION OF THE COMPARISON PROCESS

The analysis of the above chapter has focused on the subsidisation of drugs that the ubsidising agency wishes to see subsidised. Where drugs are considered low priority additions o the basket of subsidised treatment options either delays may occur in subsidisation or no ubsidies will be offered. Under the JZ scheme drugs that represent small improvements could)e accommodated by allowing a longer time threshold for subsidisation or through the use of a :cheme that incorporates increased consumer part payments through the levying of at least a)ortion of marginal cost to the patient. Under the RP scheme such drugs may face significant delays and in order to be subsidised the firm may have to make concessions elsewhere. One

xample of such a case is in that of Famvir which was listed only after SmithKline and Beecham greed to reduce the price of Tagamet, an existing drug in an unrelated subgroup, by 40 percent. Vhile such a move may well have occurred under the JZ scheme other options were available in der to see Famvir subsidised. It is not clear that this was the case under reference pricing.

One weakness of the comparison process used was that it did not address the problem of ie expiration of the patent life of the incumbent. Presumably this would occur before the ntrant faced generic entry and so the profit function of the entrant may be affected. This will not ias results if a consumer price of zero is maintained for the incumbent. One worrying facet of ie modified JZ scheme is that it may deter generics from entering the market. The incumbent as previously been assumed to dominate the generic for all consumers. If consumers are faced 'ith a choice between an incumbent drug pricing at zero and a positive price for an unsubsidised eneric it is clear that the generic will not gain any market share. A JZ-type scheme, in practice, 'ould need to be designed to allow for the expiration of a firm's contract if generics are to be ncouraged. Further research would need to be undertaken in this area before the JZ scheme ould be recommended without serious reservations.

A future avenue of research lies in the possibility that firms may use the prices of other ariables as strategic variables. Here the firms offer to decrease the price of an unrelated drug to btain listing on the Pharmaceutical Schedule. There are two general ways in which this occurs, ie first of which has been covered above with the Tagament-Famvir deal. Pharmac has also hown a willingness to relax its restriction on drugs joining a market below the reference price 'here firms are willing to decrease prices elsewhere.[53] This is significant where the drug to be isted represents an improvement on the drugs already in the subgroup since this type of deal may e used to circumvent the problem of insufficient subsidisation under reference pricing referred o above.

[53] In January 1998, it was reported that Pharmac were negotiating with respect to Parke Davis's tatin Lipitor® (chemical name Atorvastatin) with a view to it entering the statin subgroup in return for lecreasing the producer price of Accupril®, its Ace inhibitor, by 60%. Atorvastatin has been found to be wice as potent on a mg per cholesterol lower basis as Zocor® (from Merck Sharpe and Dohme) in short erm trials. It is assumed that long term mortality/morbidity trials are continuing. Atorvastatin® was proposed to enter at above the current reference price for statins.

CHAPTER 11

SUMMARY

Subsidisation of pharmaceuticals is likely to become a more contentious topic in the future s governments worldwide continue to look for ways to reduce the cost of health care. The ıstitutions and mechanisms put in place to aid subsidisation are vital to the success of a nation ı limiting the pharmaceutical budget to only that required to make fair contributions to research nd development. This thesis has attempted to analyse two options available to governments. eference pricing has been shown theoretically to be expensive where adequate restrictions are ot placed on the operating policies of the pharmaceutical agency. Where these restrictions are sed by the agency reference pricing becomes unreliable, giving no guarantee that worthwhile rugs will be subsidised. The analysis of Zammit-Lucia and Dasgupta (1995) has shown that /here reference pricing has been successful, it was only so for a short time.

In New Zealand the rate of growth was arrested after the introduction of reference pricing. 'he problems Pharmac faced keeping spending within its notional budget in 1997 indicate that ıe period of efficacy for reference pricing may be drawing to an end. The JZ variant outlined oes appears to be far from an ideal replacement for reference pricing though. The JZ scheme is ıore reliable than reference pricing as well as being generally less expensive but the delay it equires before subsidisation generally lowers both consumer surplus and efficiency. Rather than ıresent all the possible expansions of the model in this summary I have opted to place the ıajority of them at the end of each chapter. The most serious questions left to are however aised below:

(a) Patent integrity under marginal cost pricing: in Section XI of Chapter 10 the patent ystem was found to maintain its integrity where a fixed charge of zero was used. Under narginal cost pricing the JZ scheme might not, in general, give firms the same profits they would ıave enjoyed in an unregulated market.

(b) Simultaneous entry: the JZ model analysed did not attempt to ascertain what the likely :ffect of firms simultaneously attempting to obtain subsidisation under the JZ scheme would be. As most activity after the introduction of the JZ scheme would involve the subsidisation of ɔre-existing groups of drugs this would have to be considered. Rent seeking may also become a ;erious problem.

(c) Generic entry: a mechanism would have to be designed to encourage generic entry ecause, as yet, the question of why a generic would wish to enter a JZ regulated market remains nanswered.

(d) Other informational asymmetries: in Chapters 7 and 10 the agency was assumed to now the true characteristics of drugs as well as fixed costs. Under imperfect knowledge a ignalling mechanism will likely be used to form a new variant of the JZ scheme. The nature of iis mechanism is difficult to determine without in-depth analysis but it is likely that it would ivolve either signalling with an additional variable or partial revelation of information. Under artial revelation of information firms of particular types signal at a given time. While the gency cannot tell the exact type of firm that has signalled it does know which firms choose to ignal at that time and can act accordingly.

(e) An alternative view of the pharmaceutical market: the view of the pharmaceutical iarket taken here saw that the majority of firms have independent distributions of drug quality. 'he pharmaceutical market may be suited to a model where all firms have dependant istributions of the type explored in Chapter 8.

(f) Alternative definitions for utility: the utility function used throughout this thesis is elatively unsophisticated. A new definition for utility could incorporate two distinct effects in iat drug use (with a positive quality drug) increases earning capacity and reduces a separate tility loss specific to the signs and symptoms of the illness. It is very likely that this will not hange the predictions of the model greatly.

ACKNOWLEDGEMENTS

First and foremost I would like to thank my supervisor, Alan Woodfield, for the phenomenal job he's done this year. I've discovered that writing a thesis takes not only a lot of hard work but also a supervisor who's willing to put up with half written chapters and, shall we say, a flexible approach to deadlines. Thank you for the patience you've shown and the guidance you've given.

Thanks also go out to my family and the economics department who have supported me magnificently throughout the past year.

REFERENCES

van Asselt, H.Th. Policies on Pharmaceutical Patents: The Impact of Patent Protection on R&D. In Huttin, C. and Bosanquet, N. (1992) *The Prescription Drug Market.* Amsterdam, North-Holland.

Bester, H. (1993) Bargaining versus Price Competition in Markets with Quality Uncertainty. *American Economic Review* 83(1):278-228

Carlton, D. and Perloff, J. (1994) *Modern Industrial Organisation.* 2nd edition, Harper Collins. p 281-307.

Carruthers, N. Location choice when price is also a decision variable. *Annals of Regional Science* 1981. pp 29-42.

Cullen, R. (1982) *Regulation of Availability and Use of New Therapeutic Drugs: A USA-New Zealand Comparison.* 37p. (University of Otago Economics Discussion Papers No. 8202)

Danzon, P.M. (1997) *Pharmaceutical Price Regulation: National Policies vs Global Interests.* Washington, AEI Press. 96p.

Dasgupta, P. and Maskin, E. (1986) The existence of equilibrium in discontinuous economic games. 1: Theory. *Review of Economic Studies* 53. pp 27-42.

Davies, S. and Lyons, B. (1988) *Economics of Industrial Organisation.* Essex, Longman pp.127-165.

Davis, P. ed. (1992) *For Health or Profit? Medicine, the Pharmaceutical Industry, and the State in New Zealand.* Oxford, Oxford University Press. 298p.

Dekel, E. (1990) Simultaneous Offers and the Inefficiency of Bargaining: A Two-Period Example. *Journal of Economic Theory* 50(1):300-308.

Dickson, M. And Poullier, J-P. Prescription Reimbursement in Selected European Countries. In Huttin, C. and Bosanquet, N. (1992) *The Prescription Drug Market.* Amsterdam, North-Holland.

Eaton, B. and Lypsey, R. (1978) *Freedom of entry and the existence of pure profit. Economic Journal.* 88(351):455-469.

Frank, R. and Salkever, D. (1992) Pricing, Patent Loss and the Market for Pharmaceuticals. *Southern Economic Journal* 59(2):165-179.

Frank, R. and Salkever, D. (1997) Generic Entry and the Pricing of Pharmaceuticals. *Journal of Economics & Management Strategy* 6(1):75-90.

Fudenberg, D. and Tirole, J. (1992) *Game Theory*. MIT Press. pp 479-489.

Gambardella, A. (1995) *Science and innovation: The US pharmaceutical industry during the 1980s*. New York, Cambridge University Press. 199p.

Greene, W.H. (1993) *Econometric Analysis*. New York, Macmillan, Inc. pp.57-60.

Gross, D.J. and others. (1994) International pharmaceutical spending controls: France, Germany, Sweden, and the United Kingdom. *Health Care Financing Review* 15(3). pp. 127-140.

Grossman, S. (1989) *The Informational Role of Prices*. Cambridge Mass. and London, MIT. 218p.

Grossman, S. and Perry, M. (1986) Sequential Bargaining under Asymmetric Information. *Journal of Economic Theory* 39(1) pp. 120-154.

Gul, F. and others. (1986) Foundations of Dynamic Monopoly and the Coase Conjecture. *Journal of Economic Theory* 39(1):155-190.

Hamilton, J. (1994) Quantity Competition in a Spatial Model. *Canadian Journal of Economics* 27(4). pp.903-917.

Harrison, G.W. and Morgan, P. (1990) Search intensity in experiments. *The Economic Journal* 100(401):478-486.

Hay, D. (1976) Sequential entry and entry deterring strategies in spatial competition. *Oxford Economic Papers* 28(2):240-257.

Hotelling, H. (1929) Stability in competition. *Economic Journal*:41-57.

Johnston, M and Zeckhauser, R. (1991) *The Australian Pharmaceutical Subsidy Gambit: Transmuting Deadweight Loss and Oligopoly Rents to Consumer Surplus*. (National Bureau of Economic Research Working Paper No. 3783)

Kennan, J. and Wilson, R. (1993) Bargaining with private information. *Journal of Economic Literature* 31(1):45-104.

Kreps, D. (1990) *Game Theory and Economic Modelling*. Oxford, Oxford University Press. 195p.

Kletchko S.L. and others. (1995) *Targeting Medicines, Rationalising Resources in New Zealand; A preliminary paper*. Wellington, Pharmac. 26p.

Krouse, C. (1990) *Theory of industrial economics*. Blackwell, Massachsetts USA, . p. 63-189.

Laffont, J-J. and Tirole, J. (1993) *A Theory of Incentives in Procurement and Regulation*. Massachusetts USA, MIT Press. pp.129-155.

Lane, W. (1980) Product differentiation in a model with endogenous sequential entry. *Bell Journal of Economics* 11(1):237-260.

Linhart, P. and others eds. (1992) *Bargaining with Incomplete Information.* San Diego, Academic Press 1992 553p.

Mas-Colell, A. and others. (1995) Microeconomic Theory. New York, Oxford University Press. pp.235-295.

McNeil, B. and others. (1988) On the Framing of Medical Decisions. *In* Bell and others. *Decision Making; Descriptive, Normative and Prescriptive Interactions.* Cambridge University Press. pp. 562-568.

Nash, J.(1953) Two-Person Cooperative Games. *Econometrica* 21:128-140.

New Zealand Audit Office. (1992) Department of Health: Administration of the Pharmaceutical Benefits Scheme. Wellington, New Zealand Audit Office. pp.6-39.

Novshek, W. (1990) *Equilibrium in Simple Spatial (or Differentiated Product) Models. Journal of Economic Theory* 22(2):243-245.

Osborne, M. and Rubinstein, A. (1994) *A Course in Game Theory.* Cambridge, MIT Press. 352p.

Osborne, M. and Rubinstein, A. (1990) *Bargaining and Markets.* San Diego, CA., Academic Press, Inc. 215p.

Parker, J. (1988) *Who has a drug lag?* Dunedin, New Zealand. 24p. (University of Otago Economics Discussion Papers No. 8819).

Parker, J. (1991) *Pharmaceutical Patents in New Zealand.* Auckland, NZ, IMS(NZ) Ltd. 161p.

Parker, J. (1997) Pharmaceutical Patent Reform in New Zealand. *New Zealand Economic Papers* 31(1):85-91.

Pharmaceutical Management Agency Limited. (1993) *Operating Policies and Procedures of PHARMAC.* Wellington, Pharmac. 18p.

Pharmaceutical Management Agency Limited. (1995) *Pharmac: the first 20 months,* Wellington, Pharmac. 24p.

Pharmaceutical Management Agency Limited (1996) *Annual Report 1996.* Wellington, Pharmac. 25p.

Posner, R.A. (1992) *The Economic Analysis of Law.* Boston, Little, Brown and Company. 4th edition. pp.354-355

Reekie, W.D. (1975) *The Economics of the Pharmaceutical Industry*. London, The MacMillan Press Ltd. pp.84-117.

Reekie, W.D. and Weber, M. (1979). *Profits, Politics and Drugs*. New York, Holmes and Meier Publishers, Inc. pp.122-157.

Researched Medicines Industry Association of New Zealand. (1993) *An agenda for medicines in health: 1994 and beyond.* Wellington, RMIANZ. pp1-18.

Roth, A. (1985) ed. *Game theoretic models of bargaining: introduction and overview*. Cambridge, Cambridge University Press.

Salop, S. Monopolistic Competition with Outside Goods. (1979) *Bell Journal of Economics* 10(1):141-156.

Samuelson, W. (1994) Bargaining under Asymmetric Information. *Econometrica* 52(4):995-1005.

Sobel, J. and Takahashi, I. (1983) A Multistage Model of Bargaining. *Review of Economic Studies* 50(3):411-426.

Spivak, M. (1980) *Calculus*. Houston TX, Publish or Perish, Inc. 2nd edition. p.178.

Stokey, N. (1981) Rational Expectations and Durable Goods Pricing. *Bell Journal of Economics* 12(1):112-128.

Temin, P. (1980) *Taking your Medicine: Drug Regulation in the United States*. Cambridge, MA, Harvard University Press. 274p.

Tirole, J. (1988) *The Theory of Industrial Organisation*. Cambridge MA, The MIT Press. pp 277-304, 423-443.

Therapeutics Section, Ministry of Health. (1994) *Interchangeable Multi-source Medicines*. Ministry of Health, p.ii-ix.

Varian, H. (1992) *Microeconomic Analysis*. New York, WW Norton & Company, Inc. 3rd edition. 506p.

Woodfield, A. and others. (1997) *Money & Medicines: An Economic Analysis of Reference Pricing and Related Public-sector Cost-containment Systems for Pharmaceuticals with Special Reference to New Zealand.* Auckland, Merck Sharp & Dohme (New Zealand) Limited. 271p.

Zammit-Lucia, J. and Dasgupta, R. (1995) *Reference Pricing: The European Experience.* 31p. (St. Mary's Hospital Medical School, University of London, Health Policy Review no. 10)

APPENDICES

ɔpendix 2.1 Derivation of Expected Utility

ıe utility function of an individual consumer is:

$$_i = m - p_i q_{ij} - L(1-\varphi_{ij}\sqrt{q_{ij}}) - k.$$

ıen evaluated at the choice values of zero and one this expression becomes

$$_i\Big|_{q_{ij}=1} = \quad m - p_i - L(1-\varphi_{ij}) - k.$$

$$_i\Big|_{q_{ij}=0} = \quad m - L - k.$$

ɔw full treatment will occur only where

$$-p_i - L(1-\varphi_{ij}) - k > m - L - k.$$

$$-p_i + L\varphi_{ij} > 0$$

$$\varphi_{ij} > \frac{p_i}{L}$$

$$q_{ij} = \begin{cases} 0 & if\ \varphi_{ij} \le \frac{p_i}{L} \\ 1 & if\ \varphi_{ij} > \frac{p_i}{L} \end{cases}$$

ıe individual subscript j is removed from this point onwards. Expected utility is invariant between dividuals who know nothing about the individual-specific quality they face from the drug. As expected ility does not differ between such individuals the j subscript is redundant and is so ignored.

$$U_\lambda(p_i, p_j, \lambda_i^e, \eta_i^e)$$

$$\int_{-\infty} f_i^e(\varphi_i) U_i(\varphi_i, p_i) d\varphi_i$$

$$\int_{\frac{p_i}{L}}^{\lambda_i^e} f_i^e(\varphi_i)(m - p_i - L(1-\varphi_i) - k) d\varphi_i + \int_{-\infty}^{\frac{p_i}{L}} f_i^e(\varphi_i)(m - L - k) d\varphi_i$$

$$(m - p_i - L - k)\int_{\frac{p_i}{L}}^{\lambda_i^e} f_i^e(\varphi_i) d\varphi_i + L\int_{\frac{p_i}{L}}^{\lambda_i^e} \varphi_i f_i^e(\varphi_i) d\varphi_i + (m - L - k)\int_{-\infty}^{\frac{p_i}{L}} f_i^e(\varphi_i) d\varphi_i$$

$$(m - p_i - L - k)\left[1 - F_i^e(\tfrac{p_i}{L})\right] + L\int_{\frac{p_i}{L}}^{\lambda_i^e} \varphi_i f_i^e(\varphi_i) d\varphi_i + (m - L - k)\left[F_i^e(\tfrac{p_i}{L}) - 0\right]$$

$$(m - L - k) - p_i\left[1 - F_i^e(\tfrac{p_i}{L})\right] + L\int_{\frac{p_i}{L}}^{\lambda_i^e} \varphi_i f_i^e(\varphi_i) d\varphi_i$$

$$(m - L - k) - p_i\left[1 - F_i^e(\tfrac{p_i}{L})\right] + L\int_{\frac{p_i}{L}}^{\lambda_i^e} \eta_i^e \varphi_i e^{\eta_i^e(\varphi_i - \lambda_i^e)} d\varphi_i$$

ow since $\int ax\,e^{bx}\,dx = (\frac{a}{b}x - a)e^{bx} + C$ we can rewrite expected utility as:

$$U_i(p_i, p_j, \lambda_i^e, \eta_i^e)$$

$$(m - L - k) - p_i\left[1 - F_i^e(\tfrac{p_i}{L})\right] + L(\varphi_i - \tfrac{1}{\eta_i^e})e^{\eta_i^e(\varphi_i - \lambda_i^e)}\Big|_{\varphi_i = \frac{p_i}{L}}^{\varphi_i = \lambda_i^e}$$

$$(m - L - k) - p_i\left[1 - F_i^e(\tfrac{p_i}{L})\right] + L(\varphi_i - \tfrac{1}{\eta_i^e})F_i^e(\varphi_i)\Big|_{\varphi_i = \frac{p_i}{L}}^{\varphi_i = \lambda_i^e}$$

$$(m - L - k) - p_i\left[1 - F_i^e(\tfrac{p_i}{L})\right] + L\left[(\lambda_i^e - \tfrac{1}{\eta_i^e}) - (\tfrac{p_i}{L} - \tfrac{1}{\eta_i^e})F_i^e(\tfrac{p_i}{L})\right]$$

$$(m - L - k) - p_i + p_i F_i^e(\tfrac{p_i}{L}) + L(\lambda_i^e - \tfrac{1}{\eta_i^e}) - p_i F_i^e(\tfrac{p_i}{L}) + \tfrac{L}{\eta_i^e}F_i^e(\tfrac{p_i}{L})$$

$$(m - L - k) + L(\lambda_i^e - \tfrac{1}{\eta_i^e}) + \tfrac{L}{\eta_i^e}F_i^e(\tfrac{p_i}{L}) - p_i$$

ıppose a price is required to set expected utility equal to a value, *C*.

$$EU_i(p_i, p_j, \lambda_i^e, \eta_i^e) = C$$

$$\eta - L - k) + L(\lambda_i^e - \tfrac{1}{\eta_i^e}) + \tfrac{L}{\eta_i^e}F_i^e(\tfrac{p_i}{L}) - p_i = C$$

$$\tfrac{L}{\eta_i^e}e^{\eta_i^e(\frac{p_i}{L} - \lambda_i^e)} - p_i = C - (m - L - k) - L(\lambda_i^e - \tfrac{1}{\eta_i^e})$$

$$\tfrac{L}{\eta_i^e}e^{-\eta_i^e\lambda_i^e}e^{\frac{\eta_i^e}{L}p_i} = C - (m - L - k) - L(\lambda_i^e - \tfrac{1}{\eta_i^e})$$

which is of the general form

$$\alpha e^{\beta p} - p = \gamma$$

nfortunately problems of this form are not solvable algebraically and so numerical methods must be sed to obtain a solution to this problem.

ppendix 2.2 Some useful integrals

wo integrals will be used extensively in future appendices and rather than evaluate them in several aces within each appendix it is preferable to manipulate them here. Before these integrals can be fined however some attention must given to the question of how patients trade off the qualities of fferent drugs.

ppose both are tested. The qualities of both drugs must be known if some comparison is to be made tween them drugs so this is not a challenging assumption. The decision between drug 1, drug 2 and no ugs (when both drugs are tested) is decomposed into four separate cases dependant on the values of ch drug quality. The choices made in each circumstance are given in the following table:

	$\varphi_2 \leq \frac{p_2}{L}$	$\varphi_2 > \frac{p_2}{L}$
$_1 \leq \frac{p_1}{L}$	No drugs are purchased	Drug 2 is purchased
$_1 > \frac{p_1}{L}$	Drug 1 is purchased	Uncertain but a drug is definitely used

the case where $\varphi_1 > \frac{p_1}{L}$ and $\varphi_2 > \frac{p_2}{L}$ either treatment would be chosen if it were the only option since e qualities of both drugs are greater than the treatment threshold. Because treatment will be taken of hichever drug is selected q_{ij} is set equal to 1. The decision is made using the following process:

$$U_{1j} = m - p_1 - L(1-\varphi_{1j}) - k$$

$$U_{2j} = m - p_2 - L(1-\varphi_{2j}) - k$$

uppose $U_{1j} > U_{2j}$ then

$$-p_1 + L\varphi_{1j} > -p_2 + L\varphi_{2j}$$

$$L\varphi_{1j} > L\varphi_{2j} + (p_1 - p_2)$$

$$\varphi_{1j} > \varphi_{2j} + \frac{(p_1 - p_2)}{L}$$

o finally,

Drug 1 is chosen if $\varphi_{1j} > \varphi_{2j} + \frac{(p_1 - p_2)}{L}$

Drug 2 is chosen if $\varphi_{2j} \geq \varphi_{1j} - \frac{(p_1 - p_2)}{L}$

t_1(index, superior drug's price, inferior drug's price, upper value for quality of drug 1)

t_1 refers to the proportion of patients who:
Face a value of less than B for the quality of drug *j*
Face a quality sufficient to continue using either drug in preference to taking no treatment at all.
Change their decision as a result of a price change

$$t_1(j, p_j, p_i, B)$$

$$\int_{\frac{p_j}{L}}^{B} f_j(\varphi_j) f_i(\varphi_j - \frac{(p_j - p_i)}{L}) d\varphi_j$$

$$\int_{\frac{p_j}{L}}^{B} \eta_i \eta_j e^{\eta_j(\varphi_j - \lambda_j)} e^{\eta_i(\varphi_j - \frac{(p_j - p_i)}{L} - \lambda_i)} d\varphi_j$$

$$\int_{\frac{p_j}{L}}^{B} \eta_i \eta_j e^{-\eta_j\lambda_j - \eta_i\lambda_i - \eta_i\frac{(p_j - p_i)}{L}} e^{\eta_j\varphi_j} e^{\eta_i\varphi_j} d\varphi_j$$

$$\frac{\eta_i \eta_j}{\eta_i + \eta_j} e^{-\eta_j\lambda_j - \eta_i\lambda_i - \eta_i\frac{(p_j - p_i)}{L}} \left[e^{(\eta_i + \eta_j)\varphi_j} \right]_{\frac{p_j}{L}}^{B}$$

$$\frac{1}{\eta_i + \eta_j} \left[\eta_i \eta_j e^{-\eta_j\lambda_j - \eta_i\lambda_i - \eta_i\frac{(p_j - p_i)}{L}} e^{(\eta_i + \eta_j)\varphi_j} \right]_{\frac{p_j}{L}}^{B}$$

$$\frac{1}{\eta_i + \eta_j} \left[\left(\eta_i e^{\eta_i(\varphi_j - \frac{(p_j - p_i)}{L} - \lambda_i)} \right) \left(\eta_j e^{\eta_j(\varphi_j - \lambda_j)} \right) \right]_{\frac{p_j}{L}}^{B}$$

$$\frac{1}{\eta_i + \eta_j} \left[f_j(\varphi_j) f_i(\varphi_j - \frac{(p_j - p_i)}{L}) \right]_{\frac{p_j}{L}}^{B}$$

$$\frac{1}{\eta_i + \eta_j} \left[f_j(B) f_i(B - \frac{(p_j - p_i)}{L}) - f_j(\frac{p_j}{L}) f_i(\frac{p_j}{L} - \frac{(p_j - p_i)}{L}) \right]$$

$$\frac{1}{\eta_i + \eta_j} \left[f_j(B) f_i(B - \frac{(p_j - p_i)}{L}) - f_j(\frac{p_j}{L}) f_i(\frac{p_i}{L}) \right]$$

t_2(index, superior drug's price, inferior drug's price, upper value for quality of drug 1)

$_2$ refers to the proportion of patients who:
Faced a value of less than B for the quality of drug *j*
Face a quality sufficient to continue using either drug in preference to taking no treatment at all.
Select drug *j*

$_2(j, p_j, p_i, B)$

$$\int_{\frac{p_j}{L}}^{B} f_j(\varphi_j)F_i(\varphi_j-\frac{(p_j-p_i)}{L})d\varphi_j = \frac{1}{\eta_i}\int_{\frac{p_j}{L}}^{B} f_j(\varphi_j)f_i(\varphi_j-\frac{(p_j-p_i)}{L})d\varphi_j$$

Where $B + \frac{(p_j-p_i)}{L} < \lambda_i$

$$\frac{1}{\eta_i}\frac{1}{\eta_i+\eta_j}\left[f_j(B)f_i(B-\frac{(p_j-p_i)}{L}) - f_j(\frac{p_j}{L})f_i(\frac{p_i}{L})\right]$$

$$\frac{1}{\eta_i+\eta_j}\left[f_j(B)\frac{f_i(B-\frac{(p_j-p_i)}{L})}{\eta_i} - f_j(\frac{p_j}{L})\frac{f_i(\frac{p_i}{L})}{\eta_i}\right]$$

$$\frac{1}{\eta_i+\eta_j}\left[f_j(B)F_i(B-\frac{(p_j-p_i)}{L}) - f_j(\frac{p_j}{L})F_i(\frac{p_i}{L})\right]$$

ote: if $B + \frac{(p_j-p_i)}{L} \geq \lambda_i$ then the interval must be more precisely defined for meaningful results. The ason for this is given later where different cases are defined for the proportion of patients using specific armaceuticals.

ppendix 2.3 Proportion of patients using a particular drug

efore any analysis is undertaken the notation used must be explained. From the doctor/patient valuation l possible drug options are ranked from *1* through *N* on the basis of expected utility to the patient. This dering is dependant on the estimations that doctors and their patients hold on the values of lambda and a for each drug and not necessarily on the actual merits of particular drugs. From this point the process testing begins.

Appendix 2.2 the following decision rule was derived:

	$\varphi_2 \leq \frac{p_2}{L}$	$\varphi_2 > \frac{p_2}{L}$
$_1 \leq \frac{p_1}{L}$	No drugs are purchased	Drug 2 is purchased
$_1 > \frac{p_1}{L}$	Drug 1 is purchased	See below

Drug 1 is chosen if $\varphi_{1j} > \varphi_{2j} + \frac{(p_1 - p_2)}{L}$

Drug 2 is chosen if $\varphi_{2j} \geq \varphi_{1j} - \frac{(p_1 - p_2)}{L}$

his analysis can be generalised a sequential search case. The critical value of φ_i for accepting drug *i* ithout testing drug *j* (denoted φ_i^*) will occur where the expected utility from searching for another drug equal to the utility gained with quality φ_i^*. This value of quality will satisfy the expression:

$$EU_j - k = m - p_i - L(1 - \varphi_i^*) - k$$

$$EU_j = m - p_i - L(1 - \varphi_i^*)$$

$$\varphi_i^* = \frac{EU_j - m + p_i + L}{L}$$

xpected utility net of search cost for any marketable drug must be greater than the no treatment level *m* *L - k*.

$$EU_j - k > m - L - k$$

$$EU_j > m - L$$

$$\varphi_i^* = \frac{EU_j - m + p_i + L}{L} > \frac{m - L - m + p_i + L}{L} = \frac{p_i}{L}$$

his last statement is important when restricting cases further. The standard case explored here onsiders only two drugs which will routinely be indexed by expected utility. Drug 1 is the superior drug n this basis and will be accepted without further testing as long as $\varphi_1 > \varphi_1^*$.

n general in a two drug setting patients fall into four categories. The definition and probability for each f these outcomes are:

- $Pr(U_1 > EU_2 - k)$ is the proportion of patients who test drug 1 and find it of sufficient quality for them to accept it as the best available drug
- $Pr(U_1 > U_2, \varphi_1 > \frac{p_1}{L} | U_1 > EU_2 - k)(1 - Pr(U_1 > EU_2 - k))$ is the proportion of patients who test both drugs and find that drug 1 is superior to both taking drug 2 and taking no treatment.
- $Pr(U_2 > U_1, \varphi_2 > \frac{p_2}{L} | U_1 > EU_2 - k)(1 - \Pr(U_1 > EU_2 - k))$ is the proportion of patients who test both drugs and find that drug 2 is superior to both taking drug 1 and taking no treatment.

$Pr(\varphi_1 < \frac{p_1}{L},\ \varphi_2 < \frac{p_2}{L})$ is the proportion of patients who test both drugs and find that neither drug is of suitable quality to continue treatment.

he table given above extends easily to accommodate the sequential search case:

	$\varphi_2 \le \frac{p_2}{L}$	$\varphi_2 > \frac{p_2}{L}$
$\varphi_1 \le \frac{p_1}{L}$	No drugs are purchased	Drug 2 is purchased once the quality of drug 2 is known
$\frac{p_1}{L} < \varphi_1 \le \varphi_1^*$	Drug 1 is purchased once the quality of drug 2 is known	Drug 1 is chosen if $\varphi_1 > \varphi_2 + \frac{(p_1-p_2)}{L}$, otherwise drug 2 is chosen
$\varphi_1^* < \varphi_1$	Drug 1 is automatically chosen without testing drug 2	Drug 1 is automatically chosen without testing drug 2

emma:

$$\text{'r}(\varphi_1 > \varphi_2 + \tfrac{(p_1-p_2)}{L}, \varphi_1 > \tfrac{p_1}{L}, \varphi_1 \le \varphi_1^*, \varphi_2 > \tfrac{p_2}{L}) = \int_{\frac{p_1}{L}}^{\varphi_1^*} f_1(\varphi_1) F_2(\varphi_1 - \tfrac{(p_1-p_2)}{L}) d\varphi_1 - F_2(\tfrac{p_2}{L})[F_1(\varphi_1^*) - F_1(\tfrac{p_1}{L})]$$

$$\text{'r}(\varphi_1 > \varphi_2 + \tfrac{(p_1-p_2)}{L}, \varphi_1 > \tfrac{p_1}{L}, \varphi_1 \le \varphi_1^*, \varphi_2 > \tfrac{p_2}{L})$$

$$= \Pr(\tfrac{p_2}{L} < \varphi_2 < \varphi_1 - \tfrac{(p_1-p_2)}{L}, \tfrac{p_1}{L} < \varphi_1 \le \varphi_1^*)$$

$$= \int_{\frac{p_1}{L}}^{\varphi_1^*} \int_{\frac{p_2}{L}}^{\varphi_1 - \frac{(p_1-p_2)}{L}} f_1(\varphi_1) f_2(\varphi_2) d\varphi_2 \ d\varphi_1$$

$$= \int_{\frac{p_1}{L}}^{\varphi_1^*} f_1(\varphi_1)[F_2(\varphi_1 - \tfrac{(p_1-p_2)}{L}) - F_2(\tfrac{p_2}{L}) d\varphi_1$$

$$= \int_{\frac{p_1}{L}}^{\varphi_1^*} f_1(\varphi_1) F_2(\varphi_1 - \tfrac{(p_1-p_2)}{L}) d\varphi_1 - F_2(\tfrac{p_2}{L}) \int_{\frac{p_1}{L}}^{\varphi_1^*} f_1(\varphi_1) d\varphi_1$$

$$= \int_{\frac{p_1}{L}}^{\varphi_1^*} f_1(\varphi_1) F_2(\varphi_1 - \tfrac{(p_1-p_2)}{L}) d\varphi_1 - F_2(\tfrac{p_2}{L})[F_1(\varphi_1^*) - F_1(\tfrac{p_1}{L})]$$

'robability of Drug 1:

t_1 = Probability of not taking drug 2 + Probability of taking drug 1 after testing drug 2 and finding that rug 1 is better than both drug 2 and taking no drug at all

$$t_1 = \Pr(\varphi_1^* < \varphi_1) + \Pr(u_1 > u_2, \tfrac{p_1}{L} < \varphi_1 | \varphi_1 \le \varphi_1^*) \Pr(\varphi_1 \le \varphi_1^*)$$

$$= \Pr(\varphi_1^* < \varphi_1) + \Pr(\varphi_1 > \varphi_1 - \tfrac{(p_1-p_2)}{L}, \tfrac{p_1}{L} < \varphi_1 | \varphi_1 \le \varphi_1^*) \Pr(\varphi_1 \le \varphi_1^*)$$

$$= \Pr(\varphi_1^* < \varphi_1) + \Pr(\varphi_1 > \varphi_1 - \tfrac{(p_1-p_2)}{L}, \tfrac{p_1}{L} < \varphi_1 \le \varphi_1^*)$$

by Bayes' Theorem

$$= (1 - F_1(\varphi_1^*)) + \Pr(\varphi_1 > \varphi_2 + \tfrac{(p_1-p_2)}{L}, \tfrac{p_1}{L} < \varphi_1 \le \varphi_1^*, \varphi_2 \le \tfrac{p_2}{L}) + \Pr(\varphi_1 > \varphi_2 + \tfrac{(p_1-p_2)}{L}, \tfrac{p_1}{L} < \varphi_1 \le \varphi_1^*, \varphi_2 > \tfrac{p_2}{L})$$ splitting

ıto cases on φ_2

$$= (1 - F_1(\varphi_1^*)) + \Pr(\tfrac{p_1}{L} < \varphi_1 \le \varphi_1^*, \varphi_2 \le \tfrac{p_2}{L}) + \Pr(\varphi_1 > \varphi_2 + \tfrac{(p_1-p_2)}{L}, \tfrac{p_1}{L} < \varphi_1 \le \varphi_1^*, \varphi_2 > \tfrac{p_2}{L})$$

since the $\varphi_1 > \varphi_2 + \frac{(p_1-p_2)}{L}$ inequality must hold for the $\varphi_2 \le \frac{p_2}{L}$ case

$$= (1 - F_1(\varphi_1^*)) + \left[F_1(\varphi_1^*) - F_1(\tfrac{p_1}{L}) \right] F_2(\tfrac{p_2}{L}) + \int_{\frac{p_1}{L}}^{\varphi_1^*} f_1(\varphi_1) F_2(\varphi_1 - \tfrac{(p_1-p_2)}{L}) d\varphi_1 - F_2(\tfrac{p_2}{L})[F_1(\varphi_1^*) - F_1(\tfrac{p_1}{L})]$$

by the lemma

$$(1-F_1(\varphi_1^*))+\int_{\frac{p_1}{L}}^{\varphi_1^*} f_1(\varphi_1)F_2(\varphi_1-\tfrac{(p_1-p_2)}{L})d\varphi_1$$

$$(1-F_1(\varphi_1^*))+\mathrm{Int}_2(1,p_1,p_2,\varphi_1^*)$$

Where Int_2 is defined as in Appendix 2.1

robability of Drug 2:

$$_2 = \Pr(U_2 \geq U_1, \tfrac{p_2}{L} < \varphi_2 \mid \varphi_1 \leq \varphi_1^*)\Pr(\varphi_1 \leq \varphi_1^*)$$

$$\Pr(U_2 \geq U_1, \tfrac{p_2}{L} < \varphi_2, \varphi_1 \leq \varphi_1^*)$$

by Bayes' Theorem

$$\Pr(\varphi_2 \geq \varphi_1 - \tfrac{(p_1-p_2)}{L}, \tfrac{p_2}{L} < \varphi_2, \varphi_1 \leq \varphi_1^*)$$

$$\Pr(\tfrac{p_2}{L} < \varphi_2, \varphi_1 \leq \varphi_1^*) - \Pr(\varphi_1 > \varphi_2 + \tfrac{(p_1-p_2)}{L}, \tfrac{p_2}{L} < \varphi_2, \varphi_1 \leq \varphi_1^*)$$

$$F_1(\varphi_1^*)(1-F_2(\tfrac{p_2}{L})) - \left(\int_{\frac{p_1}{L}}^{\varphi_1^*} f_1(\varphi_1)F_2(\varphi_1-\tfrac{(p_1-p_2)}{L})d\varphi_1 - F_2(\tfrac{p_2}{L})\left[F_1(\varphi_1^*)-F_1(\tfrac{p_1}{L})\right]\right)$$

by the lemma

$$F_1(\varphi_1^*)-F_1(\varphi_1^*)F_2(\tfrac{p_2}{L})-\int_{\frac{p_1}{L}}^{\varphi_1^*} f_1(\varphi_1)F_2(\varphi_1-\tfrac{(p_1-p_2)}{L})d\varphi_1+F_1(\varphi_1^*)F_2(\tfrac{p_2}{L})-F_1(\tfrac{p_1}{L})F_2(\tfrac{p_2}{L})$$

$$F_1(\varphi_1^*)-\int_{\frac{p_1}{L}}^{\varphi_1^*} f_1(\varphi_1)F_2(\varphi_1-\tfrac{(p_1-p_2)}{L})d\varphi_1-F_1(\tfrac{p_1}{L})F_2(\tfrac{p_2}{L})$$

$$F_1(\varphi_1^*)-\mathrm{Int}_2(1,p_1,p_2,\varphi_1^*)-F_1(\tfrac{p_1}{L})F_2(\tfrac{p_2}{L})$$

robability of no drug being used:

he probability of no use is the probability that both drugs are of such poor quality for a patient that they ould choose to use neither drug. This probability is equal to $\mu_N=F_1(\frac{p_1}{L})F_2(\frac{p_2}{L})$.

heck on the sum of probabilities:

$$\Pr(\text{Drug 1}) + \Pr(\text{Drug 2}) + \Pr(\text{No Drugs})$$

$$[(1-F_1(\varphi_1^*)) + \mathrm{Int}_2(1,p_1,p_2,\varphi_1^*)] + [F_1(\varphi_1^*)-\mathrm{Int}_2(1,p_1,p_2,\varphi_1^*) - F_2(\tfrac{p_2}{L})F_1(\tfrac{p_1}{L})] + [F_2(\tfrac{p_2}{L})F_1(\tfrac{p_1}{L})]$$

$$1-F_1(\varphi_1^*)+F_1(\varphi_1^*) + \mathrm{Int}_2(1,p_1,p_2,\varphi_1^*)- \mathrm{Int}_2(1,p_1,p_2,\varphi_1^*) - F_2(\tfrac{p_2}{L})F_1(\tfrac{p_1}{L})+F_2(\tfrac{p_2}{L})F_1(\tfrac{p_1}{L})$$

$$1$$

urther refinement of probabilities

ıe algebraic complexity of the probabilities given above is small compared to the actual complexity hen evaluated. The distribution of adverse side effects is assumed to be exponential in this model. The obability density function of the strictly positive exponential distribution is

$$f_\varepsilon(\varepsilon)=\begin{cases}\eta e^{-\eta\varepsilon} & \text{if } \varepsilon \geq 0\\ 0 & \text{if } \varepsilon < 0\end{cases},$$

hile the cumulative distribution is

$$F_\varepsilon(\varepsilon)=\begin{cases}e^{-\eta\varepsilon} & \text{if } \varepsilon \geq 0\\ 0 & \text{if } \varepsilon < 0\end{cases}.$$

he probability and cumulative density functions for quality can be evaluated once the side effect ε has ɔen subtracted from the fixed efficacy of the drug λ. The range $[0, \infty)$ for the side effect (where $f_\varepsilon(\varepsilon)$ is ɔsitive) corresponds to the range $(-\infty, \lambda]$. Only over this range is the evaluation $f(\varphi)=\eta e^{-\eta(\lambda-\varphi)}$ correct. he full definition for the cumulative and probability density functions for drug quality are:

nce $\varphi = \lambda - \varepsilon$, $\varepsilon = \lambda - \varphi$

$$f(\varphi)=f_\varepsilon(\lambda-\varphi) = \begin{cases}\eta e^{-\eta(\lambda-\varphi)} & \text{if } \varepsilon \geq 0\ (\varphi \leq \lambda)\\ 0 & \text{if } \varepsilon < 0\ (\varphi > \lambda)\end{cases}$$

$$= \begin{cases}\eta e^{\eta(\varphi-\lambda)} & \text{if } \varphi \leq \lambda\\ 0 & \text{if } \varphi > \lambda\end{cases}$$

ıd $$F(\varphi)=\begin{cases}\eta e^{\eta(\varphi-\lambda)} & \text{if } \varphi \leq \lambda\\ 1 & \text{if } \varphi > \lambda\end{cases}.$$

nfortunately there is no guarantee that in the evaluation of Int_2 required to find the proportion of users of ıch drug will include references to $F_2(\varphi_2)$ only where $\varphi_2<\lambda_2$. The integral

$$\int_{\frac{p_1}{L}}^{\varphi_1^*} f_1(\varphi_1)F_2\left(\varphi_1-\tfrac{(p_1-p_2)}{L}\right)d\varphi_1$$

ıay indeed include some values of $\varphi_1-\frac{(p_1-p_2)}{L}$ above λ_2. This problem occurs for some values of φ_1 henever $\varphi_1^* - \frac{(p_1-p_2)}{L} > \lambda_2$. For these values the simple evaluation outlined above will be incorrect. This roblem necessitates a more thorough examination of the expressions found for the consumption of drug and drug 2 above.

he practicalities of this problem in addition to some others covered in Appendix 3.? deem that a umerical solution be used when evaluating the results of this model.

ie probability of drug 1

$\lambda_2 > \varphi_1^* - \frac{(p_1-p_2)}{L}$ then $F_2(\varphi_1^* - \frac{(p_1-p_2)}{L})<1$ and $\mu_1 = (1-F_1(\varphi_1^*)) + \int_{\frac{p_1}{L}}^{\varphi_1^*} f_1(\varphi_1)F_2(\varphi_1 - \frac{(p_1-p_2)}{L})d\varphi_1$ as before.

$\lambda_2 \leq \varphi_1^* - \frac{(p_1-p_2)}{L}$ however:

$$_1 = (1-F_1(\varphi_1^*)) + \int_{\frac{p_1}{L}}^{\varphi_1^*} f_1(\varphi_1)F_2(\varphi_1 - \frac{(p_1-p_2)}{L})d\varphi_1$$

$$(1-F_1(\varphi_1^*)) + \int_{\frac{p_1}{L}}^{\lambda_2+\frac{(p_1-p_2)}{L}} f_1(\varphi_1)F_2(\varphi_1 - \frac{(p_1-p_2)}{L})d\varphi_1 + \int_{\lambda_2+\frac{(p_1-p_2)}{L}}^{\varphi_1^*} f_1(\varphi_1)F_2(\varphi_1 - \frac{(p_1-p_2)}{L})d\varphi_1$$

$$(1-F_1(\varphi_1^*)) + \int_{\frac{p_1}{L}}^{\lambda_2+\frac{(p_1-p_2)}{L}} f_1(\varphi_1)F_2(\varphi_1 - \frac{(p_1-p_2)}{L})d\varphi_1 + \int_{\lambda_2+\frac{(p_1-p_2)}{L}}^{\varphi_1^*} f_1(\varphi_1)d\varphi_1$$

$$(1-F_1(\varphi_1^*)) + \int_{\frac{p_1}{L}}^{\lambda_2+\frac{(p_1-p_2)}{L}} f_1(\varphi_1)F_2(\varphi_1 - \frac{(p_1-p_2)}{L})d\varphi_1 + F_1(\varphi_1^*) - F_1(\lambda_2+\frac{(p_1-p_2)}{L})$$

$$(1-F_1(\lambda_2+\frac{(p_1-p_2)}{L})) + \int_{\frac{p_1}{L}}^{\lambda_2+\frac{(p_1-p_2)}{L}} f_1(\varphi_1)F_2(\varphi_1 - \frac{(p_1-p_2)}{L})d\varphi_1$$

$$(1-F_1(\lambda_2+\frac{(p_1-p_2)}{L})) + \mathrm{Int}_2(1, p_1, p_2, \lambda_2+\frac{(p_1-p_2)}{L})$$

his formula for the consumption of drug 1 bears a great deal of resemblance to the earlier case of this obability. Note that in this case if perceived quality of drug 1 is less than φ_1^* drug 2 will still be tested it unless it attains a higher level of quality than this, drug 1 will definitely be taken. To examine the nplications of this case occurring we can look at what it means for the patient's initial estimates of oduct quality.

$$\varphi_i^*(EU_j) = \frac{EU_j - m + p_i + L}{L}$$

$$\varphi_1^*(EU_2) - \frac{(p_1-p_2)}{L} > \lambda_2$$

$$\frac{EU_2 - m + p_1 + L}{L} - \frac{(p_1-p_2)}{L} > \lambda_2$$

$$\frac{EU_2 - m + p_2 + L}{L} > \lambda_2$$

$$\varphi_2^*(EU_2) > \lambda_2$$

low as $\varphi_i^*(EU_j)$ is the level of drug i required to achieve the level of expected utility for drug j we can e that the quality of drug 2 never reaches the level of its own expected utility. The expectation of drug 's quality is grossly incorrect and renders this an unlikely case although still must be considered.

he probability of drug 2

he probability of the inferior drug is subject to these same considerations. If $\lambda_2 \leq \varphi_1^* - \frac{(p_1-p_2)}{L}$ then:

$$_2 = F_1(\varphi_1^*) - \int_{\frac{p_1}{L}}^{\varphi_1^*} f_1(\varphi_1) F_2(\varphi_1 - \tfrac{(p_1-p_2)}{L}) d\varphi_1 - F_1(\tfrac{p_1}{L}) F_2(\tfrac{p_2}{L})$$

$$F_1(\varphi_1^*) - F_1(\tfrac{p_1}{L}) F_2(\tfrac{p_2}{L}) - \int_{\lambda_2+\frac{(p_1-p_2)}{L}}^{\varphi_1^*} f_1(\varphi_1) F_2(\varphi_1 - \tfrac{(p_1-p_2)}{L}) d\varphi_1 - \int_{\frac{p_1}{L}}^{\lambda_2+\frac{(p_1-p_2)}{L}} f_1(\varphi_1) F_2(\varphi_1 - \tfrac{(p_1-p_2)}{L}) d\varphi_1$$

$$F_1(\varphi_1^*) - F_1(\tfrac{p_1}{L}) F_2(\tfrac{p_2}{L}) - \int_{\lambda_2+\frac{(p_1-p_2)}{L}}^{\varphi_1^*} f_1(\varphi_1) d\varphi_1 - \int_{\frac{p_1}{L}}^{\lambda_2+\frac{(p_1-p_2)}{L}} f_1(\varphi_1) F_2(\varphi_1 - \tfrac{(p_1-p_2)}{L}) d\varphi_1$$

$$F_1(\varphi_1^*) - F_1(\tfrac{p_1}{L}) F_2(\tfrac{p_2}{L}) - (F_1(\varphi_1^*) - F_1(\lambda_2 + \tfrac{(p_1-p_2)}{L})) - \int_{\frac{p_1}{L}}^{\lambda_2+\frac{(p_1-p_2)}{L}} f_1(\varphi_1) F_2(\varphi_1 - \tfrac{(p_1-p_2)}{L}) d\varphi_1$$

$$F_1(\lambda_2 + \tfrac{(p_1-p_2)}{L}) - F_1(\tfrac{p_1}{L}) F_2(\tfrac{p_2}{L}) - \int_{\frac{p_1}{L}}^{\lambda_2+\frac{(p_1-p_2)}{L}} f_1(\varphi_1) F_2(\varphi_1 - \tfrac{(p_1-p_2)}{L}) d\varphi_1$$

$$F_1(\lambda_2 + \tfrac{(p_1-p_2)}{L}) - F_1(\tfrac{p_1}{L}) F_2(\tfrac{p_2}{L}) - \mathrm{Int}_2(I, p_1, p_2, \lambda_2 + \tfrac{(p_1-p_2)}{L})$$

ıs observed earlier this equation is again the $\lambda_2 > \varphi_1^* - \frac{(p_1-p_2)}{L}$ case with $\lambda_2 + \frac{(p_1-p_2)}{L}$ substituted for φ_1^*.

'ummary of probabilities

'he probability of the superior drug is equal to:

$(1 - F_1(\varphi_1^*)) + \mathrm{Int}_2(I, p_1, p_2, \varphi_1^*)$ if $\lambda_2 > \varphi_1^* - \frac{(p_1-p_2)}{L}$

nd $(1 - F_1(\lambda_2 + \frac{(p_1-p_2)}{L})) + \mathrm{Int}_2(I, p_1, p_2, \lambda_2 + \frac{(p_1-p_2)}{L})$ if $\lambda_2 \leq \varphi_1^* - \frac{(p_1-p_2)}{L}$

'his expression can be simplified to give

$t_1 = (1 - F_1(X)) + \mathrm{Int}_2(I, p_1, p_2, X)$ where $X = \min(\varphi_1^*, \lambda_2 + \frac{(p_1-p_2)}{L})$

ınd likewise the probability of the inferior drug being used in treatment is:

$t_2 = F_1(X) - \mathrm{Int}_2(I, p_1, p_2, X) - F_1(\frac{p_1}{L}) F_2(\frac{p_2}{L})$ where $X = \min(\varphi_1^*, \lambda_2 + \frac{(p_1-p_2)}{L})$

ppendix 3.1 The responsiveness of quantity to a drug's own price

o find a profit maximising producer's best response functions we must first find $\frac{\partial \mu_1}{\partial p_1}$ since:

$$\pi_1 = (p_1 - c_1)\mu_1, \quad \frac{\partial \pi_1}{\partial p_1} = \mu_1 + (p_1 - c_1)\frac{\partial \mu_1}{\partial p_1}.$$

his evaluation must be approached in a piecewise fashion since the equation for the quantity demanded f a particular drug is sensitive to the expected utility of the drug compared to its competitors. Note: in is appendix price changes are phrased as increases because while decreases are equally valid omparison between cases is simpler with consistent terminology.

ASE 1: $EU_1 > EU_2$ and $\varphi_1^* - \frac{(p_1 - p_2)}{L} < \lambda_2$.

he probability of drug 1 being selected by a consumer is μ_1 and the profit achieved per consumer is π_1 here:

$$\begin{aligned}
\mu_1 &= (1 - F_1(X)) + \mathrm{Int}_2(I, p_1, p_2, X), \qquad X = \min(\varphi_1^*, \lambda_2 + \tfrac{(p_1 - p_2)}{L}) \\
&= (1 - F_1(\varphi_1^*)) + \mathrm{Int}_2(I, p_1, p_2, \varphi_1^*) \\
&= (1 - F_1(\varphi_1^*)) + \int_{\frac{p_1}{L}}^{\varphi_1^*} f_1(\varphi_1) F_2(\varphi_1 - \tfrac{(p_1 - p_2)}{L}) d\varphi_1
\end{aligned}$$

$$\frac{\partial \mu_1}{\partial p_1} = -\frac{\partial \varphi_1^*}{\partial p_1} f_1(\varphi_1^*) + \frac{\partial}{\partial p_1} \int_{\frac{p_1}{L}}^{\varphi_1^*} f_1(\varphi_1) F_2(\varphi_1 - \tfrac{(p_1 - p_2)}{L}) d\varphi_1$$

$$\text{now} \frac{\partial}{\partial x} \int_{a(x)}^{b(x)} c(t,x)dt = c(b(x),x)b'(x) - c(a(x),x)a'(x) + \int_{a(x)}^{b(x)} \frac{\partial}{dx} c(t,x)dt \quad \text{so}$$

$$\begin{aligned}
\frac{\partial \mu_1}{\partial p_1} &= -\frac{\partial \varphi_1^*}{\partial p_1} f_1(\varphi_1^*) + f_1(\varphi_1^*) F_2(\varphi_1^* - \tfrac{(p_1 - p_2)}{L}) \frac{\partial \varphi_1^*}{\partial p_1} - f_1(\tfrac{p_1}{L}) F_2(\tfrac{p_1}{L} - \tfrac{(p_1 - p_2)}{L}) \frac{\partial \frac{p_1}{L}}{\partial p_1} \\
&\quad + \int_{\frac{p_1}{L}}^{\varphi_1^*} \frac{\partial}{\partial p_1} f_1(\varphi_1) F_2(\varphi_1 - \tfrac{(p_1 - p_2)}{L}) d\varphi_1 \\
&= \frac{\partial \varphi_1^*}{\partial p_1} f_1(\varphi_1^*)(F_2(\varphi_1^* - \tfrac{(p_1 - p_2)}{L}) - 1) - f_1(\tfrac{p_1}{L}) F_2(\tfrac{p_2}{L}) \frac{\partial \frac{p_1}{L}}{\partial p_1} + (-\tfrac{1}{L}) \int_{\frac{p_1}{L}}^{\varphi_1^*} f_1(\varphi_1) f_2(\varphi_1 - \tfrac{(p_1 - p_2)}{L}) d\varphi_1 \\
&= -\tfrac{1}{L} f_1(\varphi_1^*)(1 - F_2(\varphi_1^* - \tfrac{(p_1 - p_2)}{L})) - \tfrac{1}{L} f_1(\tfrac{p_1}{L}) F_2(\tfrac{p_2}{L}) - \tfrac{1}{L} \mathrm{Int}_1(I, p_1, p_2, \varphi_1^*)
\end{aligned}$$

he expression for $\frac{\partial \mu_1}{\partial p_1}$ is composed of three terms which each have an intuitive meaning. The first term ddresses the proportion of consumers who previously accepted drug 1 without testing drug 2 but will ow choose to check drug 2 after the price change. Of these consumers the proportion $F_2(\varphi_1^* - \frac{(p_1 - p_2)}{L})$ vill choose to take drug 1 even after testing the quality of drug 2.

he second term deals with the increased number of consumers who find that no treatment represents heir best option in treatment. The proportion $\frac{1}{L} f_1(\frac{p_1}{L})$ find that it is no longer worthwhile to use drug 1 in reference to taking no treatment. Of these consumers $F_2(\frac{p_2}{L})$ will also face a quality of drug 2 nsufficient to choose it as a form of treatment either. In total the proportion $\frac{1}{L} f_1(\frac{p_1}{L}) F_2(\frac{p_2}{L})$ choose to use neither drug directly as a result of an increase in the price of drug 1.

final term[1] considers those patients who test both drugs both before and after the price increase. Int_1 :s the proportion of changes of drug choice at the margin as a result of the price change.

;E 2: $EU_1>EU_2$ and $\varphi_1^* - \frac{(p_1-p_2)}{L} > \lambda_2$.

: outcome of this case bears much resemblance to the previous case. We can begin in the same ıion as before:

$$\mu_1 = (1-F_1(X))+Int_2(I,p_1,p_2,X), \qquad X=\min(\varphi_1^*,\lambda_2+\tfrac{(p_1-p_2)}{L})$$
$$= (1-F_1(\lambda_2+\tfrac{(p_1-p_2)}{L}))+Int_2(I,p_1,p_2,\lambda_2+\tfrac{(p_1-p_2)}{L})$$
$$= (1-F_1(\lambda_2+\tfrac{(p_1-p_2)}{L}))+\int_{\frac{p_1}{L}}^{\lambda_2+\frac{(p_1-p_2)}{L}} f_1(\varphi_1)F_2(\varphi_1-\tfrac{(p_1-p_2)}{L})d\varphi_1$$

$$\frac{\partial\mu_1}{\partial p_1} = -\tfrac{1}{L}f_1(\lambda_2+\tfrac{(p_1-p_2)}{L})+\tfrac{1}{L}f_1(\lambda_2+\tfrac{(p_1-p_2)}{L})F_2(\lambda_2+\tfrac{(p_1-p_2)}{L}-\tfrac{(p_1-p_2)}{L})$$
$$-\tfrac{1}{L}f_1(\tfrac{p_1}{L})F_2(\tfrac{p_1}{L}-\tfrac{(p_1-p_2)}{L})+\tfrac{1}{L}\int_{\frac{p_1}{L}}^{\lambda_2+\frac{(p_1-p_2)}{L}} f_1(\varphi_1)f_2(\varphi_1-\tfrac{(p_1-p_2)}{L})d\varphi_1$$
$$= -\tfrac{1}{L}f_1(\lambda_2+\tfrac{(p_1-p_2)}{L})\left[1-F_2(\lambda_2+\tfrac{(p_1-p_2)}{L}-\tfrac{(p_1-p_2)}{L})\right]-\tfrac{1}{L}f_1(\tfrac{p_1}{L})F_2(\tfrac{p_2}{L})+$$
$$\tfrac{1}{L}\int_{\frac{p_1}{L}}^{\lambda_2+\frac{(p_1-p_2)}{L}} f_1(\varphi_1)f_2(\varphi_1-\tfrac{(p_1-p_2)}{L})d\varphi_1$$
$$= -\tfrac{1}{L}f_1(\lambda_2+\tfrac{(p_1-p_2)}{L})\left[1-F_2(\lambda_2)\right]-\tfrac{1}{L}f_1(\tfrac{p_1}{L})F_2(\tfrac{p_2}{L})+\tfrac{1}{L}\int_{\frac{p_1}{L}}^{\lambda_2+\frac{(p_1-p_2)}{L}} f_1(\varphi_1)f_2(\varphi_1-\tfrac{(p_1-p_2)}{L})d\varphi_1$$
$$= -\tfrac{1}{L}f_1(\tfrac{p_1}{L})F_2(\tfrac{p_2}{L})+\tfrac{1}{L}Int_1(I,p_1,p_2,\lambda_2+\tfrac{(p_1-p_2)}{L})$$

e expression for $\frac{\partial\mu_1}{\partial p_1}$ is composed of two terms in this case. The first term of the earlier case no longer ɔears. Appendix 2.3 found that in this case drug 2 never achieves its own expected utility implying t the patients expectation of the quality distribution for drug 2 is incorrect. This estimation leads to a ue for φ_1^* less than that which would have prevailed if the true characteristics of drug 2 were known.

φ_1^* the value of drug 1 equals the expected utility of drug 2 which is in turn greater than any possible ılity for drug 2. Patients choosing to check drug 2 only as a result of an increase in the price of drug 1 d that the value of drug 1 to them is in excess of the value of drug 2 they observe. All consumers ɔosing to test drug 2 as a direct result of the price increase will choose to use drug 1. The firm ɔducing drug 1 has lost none of the custom of those consumers who now choose to test drug 2 and so such loss appears in the expression above.

e first and second terms correspond to those found in the previous case; the first term is identical to its ınterpart while the third term takes $\lambda_2+\frac{(p_1-p_2)}{L}$ as an input. Drug 1 will always be superior to drug 2 ıerever the quality of drug 1 is above $\lambda_2+\frac{(p_1-p_2)}{L}$ so no marginal changes will occur and so qualities ɔve this level will not be of interest when evaluating the integral.

.s defined in Appendix 2.2

CASE 3: $EU_2 > EU_1$ and $\varphi_2^* - \frac{(p_2-p_1)}{L} < \lambda_1$.

From Appendix 2.2 if drug 1 is the inferior drug then:

$$\mu_1 = F_2(X) - F_2(\tfrac{p_2}{L})F_1(\tfrac{p_1}{L}) - \mathrm{Int}_2(2, p_2, p_1, X), \qquad X = \min(\lambda_1 + \tfrac{(p_2-p_1)}{L}, \varphi_2^*)$$
$$= F_2(\varphi_2^*) - F_2(\tfrac{p_2}{L})F_1(\tfrac{p_1}{L}) - \mathrm{Int}_2(2, p_2, p_1, \varphi_2^*)$$
$$= F_2(\varphi_2^*) - F_2(\tfrac{p_2}{L})F_1(\tfrac{p_1}{L}) - \int_{\frac{p_2}{L}}^{\varphi_2^*} f_2(\varphi_2)F_1(\varphi_2 - \tfrac{(p_2-p_1)}{L})d\varphi_2$$

$$\frac{\partial \mu_1}{\partial p_1} = \frac{\partial \varphi_2^*}{\partial p_1} f_2(\varphi_2^*) - \tfrac{1}{L} F_2(\tfrac{p_2}{L}) f_1(\tfrac{p_1}{L}) - \frac{\partial \varphi_2^*}{\partial p_1} f_2(\varphi_2^*) F_1(\varphi_2^* - \tfrac{(p_2-p_1)}{L})$$
$$- \tfrac{1}{L} \int_{\frac{p_2}{L}}^{\varphi_2^*} f_2(\varphi_2) f_1(\varphi_2 - \tfrac{(p_2-p_1)}{L}) d\varphi_2$$
$$= \frac{\partial \varphi_2^*}{\partial p_1} f_2(\varphi_2^*)(1 - F_1(\varphi_2^* - \tfrac{(p_2-p_1)}{L})) - \tfrac{1}{L} F_2(\tfrac{p_2}{L}) f_1(\tfrac{p_1}{L}) - \tfrac{1}{L} \int_{\frac{p_2}{L}}^{\varphi_2^*} f_2(\varphi_2) f_1(\varphi_2 - \tfrac{(p_2-p_1)}{L}) d\varphi_2$$

Recall[2] that $\varphi_2^* = \frac{EU_1 - m + p_2 + L}{L}$ and $EU_1(p_1, \lambda_1^e, \eta_1^e) = (m - L - k) + L(\lambda_1^e - \frac{1}{\eta_1^e}) + \frac{L}{\eta_1^e} F_1^e(\frac{p_1}{L}) - p_1$.

$$\frac{\partial \varphi_2^*}{\partial p_1} = \tfrac{1}{L} \frac{\partial EU_1}{\partial p_1} = \tfrac{1}{L}\left(\tfrac{1}{L}\tfrac{L}{\eta_1^e} f_1^e(\tfrac{p_1}{L}) - 1\right) = \tfrac{1}{L}\left(\tfrac{1}{\eta_1^e} f_1^e(\tfrac{p_1}{L}) - 1\right)$$

$$\frac{\partial \mu_1}{\partial p_1} = \frac{\partial \varphi_2^*}{\partial p_1} f_2(\varphi_2^*)(1 - F_1(\varphi_2^* - \tfrac{(p_2-p_1)}{L})) - \tfrac{1}{L} F_2(\tfrac{p_2}{L}) f_1(\tfrac{p_1}{L}) - \tfrac{1}{L} \int_{\frac{p_2}{L}}^{\varphi_2^*} f_2(\varphi_2) f_1(\varphi_2 - \tfrac{(p_2-p_1)}{L}) d\varphi_2$$
$$= \tfrac{1}{L}\left(\tfrac{1}{\eta_1^e} f_1^e(\tfrac{p_1}{L}) - 1\right) f_2(\varphi_2^*)\left(1 - F_1(\varphi_2^* - \tfrac{(p_2-p_1)}{L})\right) - \tfrac{1}{L} F_2(\tfrac{p_2}{L}) f_1(\tfrac{p_1}{L}) - \tfrac{1}{L} \mathrm{Int}_1(2, p_2, p_1, \varphi_2^*)$$

Note: $\frac{1}{\eta_1^e} f_1^e(\frac{p_1}{L}) - 1 = e^{\eta_1^e(\frac{p_1}{L} - \lambda_1)} - 1 \le 0$

As with the first case explored this outcome has three terms which correspond to the definitions given earlier. The first term once more addresses the loss in custom of patients who now change their choice of whether or not to check the price of the inferior drug. As drug 1 is now inferior on the basis of expected utility an increase in the price of drug 1 leads to a decrease in φ_2^* and results in some patients choosing not to check the quality of drug 1. Of those who now choose not to check the quality of drug 1 as a result of the price increase the proportion $F_1(\varphi_2^* - \frac{(p_2-p_1)}{L})$ would not have chosen to use drug 1 in any case. The loss of consumption in drug 1 as a result of the price increase of drug 1 is then given by the expression $\frac{\partial \varphi_2^*}{\partial p_1} f_2(\varphi_2^*)(1 - F_1(\varphi_2^* - \frac{(p_2-p_1)}{L}))$.

The second term is again the proportion of patients who find that no treatment is preferable as a result of the increase in the price of drug 1. The final term once more addresses the marginal changes in treatment choice as a result of the price increase where drug 2 gains patients formerly using drug 1.

[2] From Appendix 2.1

CASE 4: $EU_2 > EU_1$ and $\varphi_2^* - \frac{(p_2-p_1)}{L} \geq \lambda_1$.

$$\mu_1 = F_2(X) - F_2(\tfrac{p_2}{L})F_1(\tfrac{p_1}{L}) - \mathrm{Int}_2(2, p_2, p_1, X), \qquad X = \min(\lambda_1 + \tfrac{(p_2-p_1)}{L}, \varphi_2^*)$$

$$= F_2(\lambda_1 + \tfrac{(p_2-p_1)}{L}) - F_2(\tfrac{p_2}{L})F_1(\tfrac{p_1}{L}) - \mathrm{Int}_2(2, p_2, p_1, \lambda_1 + \tfrac{(p_2-p_1)}{L})$$

$$= F_2(\lambda_1 + \tfrac{(p_2-p_1)}{L}) - F_2(\tfrac{p_2}{L})F_1(\tfrac{p_1}{L}) - \int_{\frac{p_2}{L}}^{\lambda_1+\frac{(p_2-p_1)}{L}} f_2(\varphi_2)F_1(\varphi_2 - \tfrac{(p_2-p_1)}{L})\mathrm{d}\varphi_2$$

$$\frac{\partial \mu_1}{\partial p_1} = -\tfrac{1}{L} f_2(\lambda_1 + \tfrac{(p_2-p_1)}{L}) - \tfrac{1}{L} F_2(\tfrac{p_2}{L}) f_1(\tfrac{p_1}{L}) + \tfrac{1}{L} f_2(\lambda_1 + \tfrac{(p_2-p_1)}{L}) F_1(\lambda_1 + \tfrac{(p_2-p_1)}{L} - \tfrac{(p_2-p_1)}{L})$$

$$- \tfrac{1}{L} \int_{\frac{p_2}{L}}^{\lambda_1+\frac{(p_2-p_1)}{L}} f_2(\varphi_2) f_1(\varphi_2 - \tfrac{(p_2-p_1)}{L})\mathrm{d}\varphi_2$$

$$= -\tfrac{1}{L} f_2(\lambda_1 + \tfrac{(p_2-p_1)}{L}) - \tfrac{1}{L} F_2(\tfrac{p_2}{L}) f_1(\tfrac{p_1}{L}) + \tfrac{1}{L} f_2(\lambda_1 + \tfrac{(p_2-p_1)}{L}) F_1(\lambda_1) - \tfrac{1}{L} \int_{\frac{p_2}{L}}^{\lambda_1+\frac{(p_2-p_1)}{L}} f_2(\varphi_2) f_1(\varphi_2 - \tfrac{(p_2-p_1)}{L})\mathrm{d}\varphi_2$$

$$= -\tfrac{1}{L} f_2(\lambda_1 + \tfrac{(p_2-p_1)}{L}) + \tfrac{1}{L} f_2(\lambda_1 + \tfrac{(p_2-p_1)}{L}) - \tfrac{1}{L} F_2(\tfrac{p_2}{L}) f_1(\tfrac{p_1}{L}) - \tfrac{1}{L} \int_{\frac{p_2}{L}}^{\lambda_1+\frac{(p_2-p_1)}{L}} f_2(\varphi_2) f_1(\varphi_2 - \tfrac{(p_2-p_1)}{L})\mathrm{d}\varphi_2$$

$$= -\tfrac{1}{L} F_2(\tfrac{p_2}{L}) f_1(\tfrac{p_1}{L}) - \tfrac{1}{L} \mathrm{Int}_1(2, p_2, p_1, \lambda_1 + \tfrac{(p_2-p_1)}{L})$$

As in the second case only two terms appear in the expression of $\frac{\partial \mu_1}{\partial p_1}$. The first of these represents the decrease in patients treated as a result of the price increase and the second the marginal changes in the choice of drugs.

CASE 5: Suppose $EU_1 = EU_2$

The four cases covered previously give different values for the sensitivity of quantity to price. The fifth case where expected utilities are equal is problematical. Very little can be said about price sensitivity here since superior drug will always obtain a greater share of the patients than the inferior drug causing a discrete jump of quantity at the level of price that equalises expected utility.

The superior drug is always tested first and the inferior drug is tested only when the expected improvement in the value of the drug exceeds the cost of searching. As a result the superior drug is often chosen when the unobserved value of the inferior drug is actually greater than the observed value of the superior drug. The superior drug gains and the inferior drug loses these consumers simply because of their respective status. This phenomena causes a discontinuity in quantity at the price where expected utilities are equal since at an epsilon below this level the drug is superior and attracts the extra consumers and at an epsilon above it must lose other consumers for the same reason.

o in summary:

$$\frac{\partial \mu_1}{\partial p_1} = \begin{cases} -\frac{1}{L} f_1(\frac{p_1}{L}) F_2(\frac{p_2}{L}) + \frac{1}{L} \mathrm{Int}_1(1, p_1, p_2, \lambda_2 + \frac{(p_1 - p_2)}{L}) & EU_1 > EU_2, \lambda_2 \le \varphi_1^* - \frac{(p_1 - p_2)}{L} \\ \frac{1}{L} f_1(\varphi_1^*)(F_2(\varphi_1^* - \frac{(p_1 - p_2)}{L}) - 1) - \frac{1}{L} f_1(\frac{p_1}{L}) F_2(\frac{p_2}{L}) & EU_1 > EU_2, \lambda_2 > \varphi_1^* - \frac{(p_1 - p_2)}{L} \\ \quad -\frac{1}{L} \mathrm{Int}_1(1, p_1, p_2, \varphi_1^*) & \\ \textit{Undefined} & EU_1 = EU_2 \\ \frac{1}{L}\left(\frac{1}{\eta_1^e} f_1^e(\frac{p_1}{L}) - 1\right) f_2(\varphi_2^*)\left(1 - F_1(\varphi_2^* - \frac{(p_2 - p_1)}{L})\right) & EU_2 \le EU_1, \lambda_1 > \varphi_2^* - \frac{(p_2 - p_1)}{L} \\ -\frac{1}{L} F_2(\frac{p_2}{L}) f_1(\frac{p_1}{L}) - \frac{1}{L} \mathrm{Int}_1(2, p_2, p_1, \varphi_2^*) & \\ -\frac{1}{L} F_2(\frac{p_2}{L}) f_1(\frac{p_1}{L}) - \frac{1}{L} \mathrm{Int}_1(2, p_2, p_1, \lambda_1 + \frac{(p_2 - p_1)}{L}) & EU_2 \le EU_1, \lambda_1 > \varphi_2^* - \frac{(p_2 - p_1)}{L} \end{cases}$$

)n closer examination the previous expression can be further simplified. The first two cases above are imply

$$\frac{1}{L} f_1(X)(F_2(X - \frac{(p_1 - p_2)}{L}) - 1) - \frac{1}{L} f_1(\frac{p_1}{L}) F_2(\frac{p_2}{L}) - \frac{1}{L} \mathrm{Int}_1(1, p_1, p_2, X)$$

with $\quad X = \min(\varphi_1^*, \lambda_2 + \frac{(p_1 - p_2)}{L})$

vhile the latter cases are

$$\frac{1}{L}\left(\frac{1}{\eta_1^e} f_1^e(\frac{p_1}{L}) - 1\right) f_2(X)\left(1 - F_1(X - \frac{(p_1 - p_2)}{L})\right) - \frac{1}{L} F_2(\frac{p_2}{L}) f_1(\frac{p_1}{L}) - \frac{1}{L} \mathrm{Int}_1(2, p_2, p_1, X)$$

with $\quad X = \min(\varphi_2^*, \lambda_1 + \frac{(p_1 - p_2)}{L})$

o

$$\frac{\partial \mu_1}{\partial p_1} = \begin{cases} -\frac{1}{L} f_1(X)(1 - F_2(X - \frac{(p_1 - p_2)}{L})) - \frac{1}{L} f_1(\frac{p_1}{L}) F_2(\frac{p_2}{L}) - \frac{1}{L} \mathrm{Int}_1(1, p_1, p_2, X) & EU_1 > EU_2 \\ \text{where} \quad X = \min(\varphi_1^*, \lambda_2 + \frac{(p_1 - p_2)}{L}) & \\ \textit{Undefined} & EU_1 = EU_2 \\ \frac{1}{L}\left(\frac{1}{\eta_1^e} f_1^e(\frac{p_1}{L}) - 1\right) f_2(X)\left(1 - F_1(X - \frac{(p_1 - p_2)}{L})\right) - \frac{1}{L} F_2(\frac{p_2}{L}) f_1(\frac{p_1}{L}) - \frac{1}{L} \mathrm{Int}_1(2, p_2, p_1, X) & EU_1 < EU_2 \\ \text{where} \quad X = \min(\varphi_2^*, \lambda_1 + \frac{(p_1 - p_2)}{L}) & \end{cases}$$

The reaction of consumption to price for drug 2 can also be found by a symmetry argument.

$$\frac{\partial \mu_2}{\partial p_2} = \begin{cases} \frac{1}{L} f_2(X)(F_1(X - \frac{(p_2 - p_1)}{L}) - 1) - \frac{1}{L} f_2(\frac{p_2}{L}) F_1(\frac{p_1}{L}) - \frac{1}{L} \mathrm{Int}_1(2, p_2, p_1, X) & EU_2 > EU_1 \\ \text{where} \quad X = \min(\varphi_2^*, \lambda_1 + \frac{(p_2 - p_1)}{L}) & \\ \textit{Undefined} & EU_2 = EU_1 \\ \frac{1}{L}\left(\frac{1}{\eta_2^e} f_2^e(\frac{p_2}{L}) - 1\right) f_1(X)\left(1 - F_2(X)\right) - \frac{1}{L} F_1(\frac{p_1}{L}) f_2(\frac{p_2}{L}) - \frac{1}{L} \mathrm{Int}_1(1, p_1, p_2, X) & EU_2 < EU_1 \\ \text{where} \quad X = \min(\varphi_1^*, \lambda_2 + \frac{(p_2 - p_1)}{L}) & \end{cases}$$

Appendix 3.2 A property of the reaction function

Over some range of prices the reaction function of firms are invariant with respect to the price of the other firm. This behaviour is unusual and is a consequence of the exponential distributions used to model individual drug qualities.

Where firm 2 accepts the status of an inferior drug (so that drug 1 is tested first in equilibrium) it attracts the quantity.

$$\mu_2 = \mathrm{F}_1(X) - \mathrm{Int}_2(I, p_1, p_2, X) - \mathrm{F}_1(\tfrac{p_2}{L})\mathrm{F}_2(\tfrac{p_2}{L}) \qquad \text{where} \quad X = \min(\varphi_1^*, \lambda_2 + \tfrac{(p_1 - p_2)}{L})$$

Assuming that $\varphi_1^* \le \lambda_2 + \frac{(p_1 - p_2)}{L}$

$$\begin{aligned}
\frac{\partial \mu_2}{\partial p_1} &= \frac{\partial}{\partial p_1}\frac{\eta_2}{\eta_2 + \eta_1}\left[e^{\eta_1(\lambda_2 + \frac{(p_1 - p_2)}{L} - \lambda_1)} - e^{\eta_1(\frac{p_1}{L} - \lambda_1)}e^{\eta_2(\frac{p_2}{L} - \lambda_2)}\right] \\
&= \frac{\eta_2}{\eta_2 + \eta_1}\left[\frac{\eta_1}{L}e^{\eta_1(\lambda_2 + \frac{(p_1 - p_2)}{L} - \lambda_1)} - \frac{\eta_1}{L}e^{\eta_1(\frac{p_1}{L} - \lambda_1)}e^{\eta_2(\frac{p_2}{L} - \lambda_2)}\right] \\
&= \frac{\eta_1\eta_2}{\eta_2 + \eta_1}\left[e^{\eta_1(\lambda_2 + \frac{(p_1 - p_2)}{L} - \lambda_1)} - e^{\eta_1(\frac{p_1}{L} - \lambda_1)}e^{\eta_2(\frac{p_2}{L} - \lambda_2)}\right] \\
&= \frac{\eta_1}{L}\mu_2
\end{aligned}$$

Now where $\varphi_1^* \le \lambda_2 + \frac{(p_1 - p_2)}{L}$ a change in the price of the superior drug shifts the quantity of the inferior drug proportionately. Let p_2^* be the profit maximising price for firm 2 for some value of p_1.

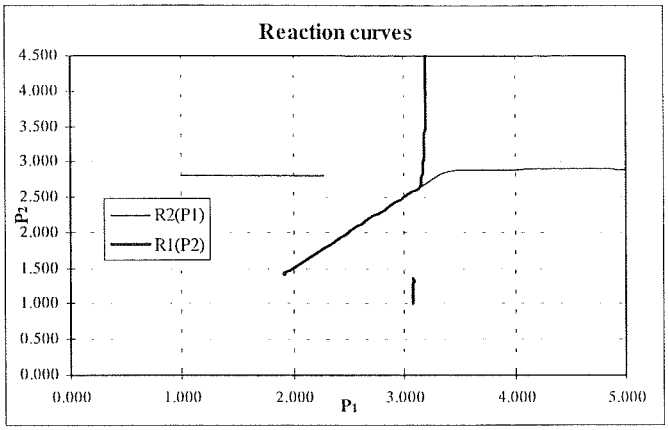
$$\begin{aligned}
\pi &= \mu_2(p_2^* - c_2) \\
0 &= \frac{\partial \mu_2}{\partial p_2}(p_2^* - c_2) + \mu_2 \\
p_2^* &= c_2 - \mu_2 / \frac{\partial \mu_2}{\partial p_2} \\
\frac{dp_2^*}{dp_1} &= -\frac{d}{dp_1}(\mu_2 / \frac{\partial \mu_2}{\partial p_2}) \\
&= \left(\frac{\partial \mu_2}{\partial p_2}\frac{\partial \mu_2}{\partial p_1} - \mu_2\frac{\partial^2 \mu_2}{\partial p_1 \partial p_2}\right)\Big/\left(\frac{\partial \mu_2}{\partial p_2}\right)^2 \\
&= \left(\frac{\partial \mu_2}{\partial p_2}\frac{\partial \mu_2}{\partial p_1} - \mu_2\frac{\partial^2 \mu_2}{\partial p_2 \partial p_1}\right)\Big/\left(\frac{\partial \mu_2}{\partial p_2}\right)^2 \\
&= \left(\frac{\partial \mu_2}{\partial p_2}\frac{\partial \mu_2}{\partial p_1} - \mu_2\frac{\partial}{\partial p_2}(\frac{\partial \mu_2}{\partial p_1})\right)\Big/\left(\frac{\partial \mu_2}{\partial p_2}\right)^2 \\
&= \left(\frac{\partial \mu_2}{\partial p_2}\frac{\eta_1}{L}\mu_2 - \mu_2\frac{\partial}{\partial p_2}(\frac{\eta_1}{L}\mu_2)\right)\Big/\left(\frac{\partial \mu_2}{\partial p_2}\right)^2 \\
&= \left(\frac{\partial \mu_2}{\partial p_2}\frac{\eta_1\mu_2}{L} - \frac{\eta_1\mu_2}{L}\frac{\partial}{\partial p_2}\mu_2\right)\Big/\left(\frac{\partial \mu_2}{\partial p_2}\right)^2 \\
&= \left(\frac{\partial \mu_2}{\partial p_2}\frac{\eta_1\mu_2}{L} - \frac{\partial \mu_2}{\partial p_2}\frac{\eta_1\mu_2}{L}\right)\Big/\left(\frac{\partial \mu_2}{\partial p_2}\right)^2 \\
&= (0)\Big/\left(\frac{\partial \mu_2}{\partial p_2}\right)^2 \\
&= 0
\end{aligned}$$

So that the optimal choice of price for an inferior firm is invariant to the competitor's price over the range where $\varphi_1^* \le \lambda_2 + \frac{(p_1 - p_2)}{L}$.

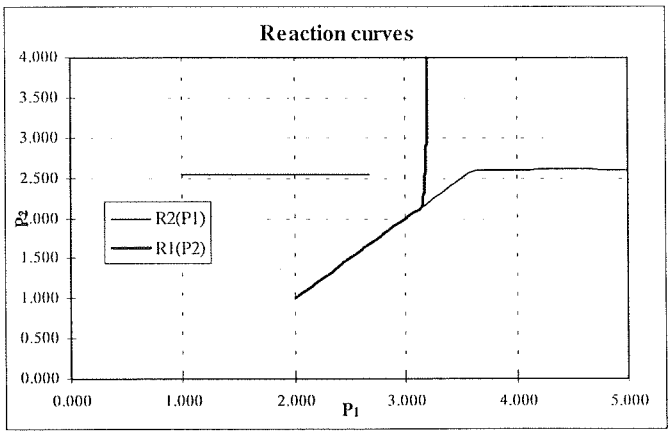
ppendix 3.3 Efficacy differentials

he following drug characteristics are assumed: $\lambda_1 = 1, \eta_1 = 1, \eta_1 = 1$.

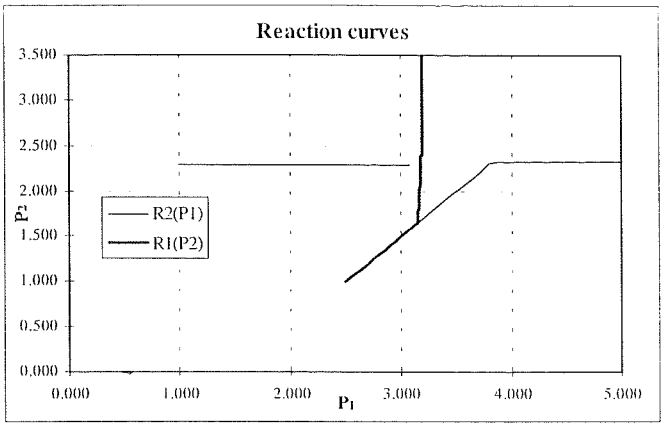
he size of the efficacy differential will determine whether or not a pure strategy equilibrium exists here the market is characterised by an unregulated duopoly. The example given in Chapter 3 uses an ;sumption of $\lambda_2 = 0.5$ which allows for a pure strategy Nash Equilibrium. With larger values of λ_2 such ıre strategy equilibria do not exist.



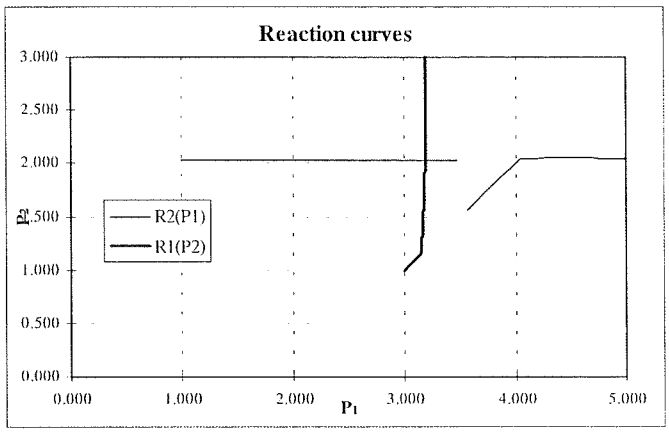
.t $\lambda_2 = 0.9$ there remains a large area where both firms undercut their competitor's price.



'he above diagram shows the reaction curves for the case where $\lambda_2 = 0.8$. With non-intersecting curves ıere is no pure strategy Nash equilibrium.



At $\lambda_2 = 0.7$ the reaction curves barely miss. There remains a small area where both firms choose to undercut. The switch point where Nash equilibria start to occur is obviously quite close to 0.7.



The final diagram displays the scenario where $\lambda_2 = 0.6$. This diagram bears a great deal of resemblance to the example given in the text with a unique Nash equilibrium in pure strategies.

ppendix 4.1 Proof of Hotelling proposition in Chapter 4

is impossible to for a firm to price its competitor out of the market where each has constant arginal costs.

firm is able to price its competitor from the market only if there exists a price so that it makes non-egative profits and its competitor makes non-positive profits. Suppose two firms exist with constant arginal cost c, are located a distance l apart and charge mill prices p_i and p_j respectively. Transport osts for a consumer of distance d away are incurred at the level td where t is common to both firms.

or firm i to price firm j from the market it must have the custom of all consumers between itself and rm j. For this to be the case the then for must every consumer between the firms and l_j away from firm

$$\begin{aligned} p_i + t(l - l_j) &\leq p_j + tl_j && \forall\, l_j \in [0,\, l] \\ p_i &\leq p_j + tl_j - t(l - l_j) && \forall\, l_j \in [0,\, l] \\ &= p_j - t(l - 2l_j) && \forall\, l_j \in [0,\, l] \end{aligned}$$

firm i is to just cover costs (and place the highest possible pressure on firm j then $p_i = c$ and

$$c + t(l - 2l_j) \leq p_j \qquad \forall\, l_j \in [0,\, l]$$

firm j is to charge a profitable price and have no market share then $\forall \varepsilon > 0$, $p_j = c + \varepsilon$ and

$$\begin{aligned} c + t(l - 2lj) &\leq c + \varepsilon && \forall\, l_j \in [0,\, l] \\ t(l - 2lj) &\leq \varepsilon && \forall\, l_j \in [0,\, l] \\ lj &\geq \tfrac{1}{2}\left(l - \frac{\varepsilon}{t}\right) && \forall\, l_j \in [0,\, l] \end{aligned}$$

he above is true if and only if it holds for the lower bound of l_j

$$\begin{aligned} 0 &\geq \tfrac{1}{2}\left(l - \frac{\varepsilon}{t}\right) \\ \varepsilon &\geq tl > 0 \end{aligned}$$

et $\varepsilon = \tfrac{1}{2}\, tl > 0$. Now $\varepsilon < tl$ which represents a contradiction since firm i does not take all the market nd firm j charges a profitable price. So it must be impossible for one firm to take the entire market in ıe Hotelling model and cover costs.

ppendix 5.1 The use of a drug under the no search model

ppendix 2.2 contains the following decision rule for the treatment chosen by a patient if the qualities of th drugs are known.

	$\varphi_2 \le \frac{p_2}{L}$	$\varphi_2 > \frac{p_2}{L}$
$_1 \le \frac{p_1}{L}$	No drugs are purchased	Drug 2 is purchased
$_1 > \frac{p_1}{L}$	Drug 1 is purchased	Drug 1 is chosen if $\varphi_1 > \varphi_2 + \frac{(p_1-p_2)}{L}$ Drug 2 is chosen if $\varphi_2 \ge \varphi_1 - \frac{(p_1-p_2)}{L}$

he proportion of patients using drug 1

rug 1 will be used only when its own quality net of price is greater than that of drug 2 and it represents better treatment option that taking no treatment at all. This can be represented by the inequalities:

$$\varphi_1 > \frac{p_1}{L} \qquad \text{and} \qquad \varphi_1 > \varphi_2 + \frac{(p_1-p_2)}{L}$$

he second inequality will be true whenever $\varphi_2 < \varphi_1 - \frac{(p_1-p_2)}{L}$. The probability of this inequality olding will be $F_2(\varphi_1 - \frac{(p_1-p_2)}{L})$ and the proportion of patients using drug 1 will be:

$$\int_{\frac{p_1}{L}}^{\lambda_1} f_1(\varphi_1) F_2(\varphi_1 - \frac{(p_1-p_2)}{L}) d\varphi_1$$

y the same rationale used in Appendix <Get correct reference> this value must be further refined since ıe simple evaluation of the integral in the Int_1 and Int_2 functions used will not be valid. If $_2 \ge \lambda_1 - \frac{(p_1-p_2)}{L}$ then the above integral can be represented by $Int_2(1,p_1,p_2,\lambda_1)$. If $\lambda_2 < \lambda_1 - \frac{(p_1-p_2)}{L}$ then ıe integral must be modified:

$$\int_{\frac{p_1}{L}}^{\lambda_1} f_1(\varphi_1) F_2(\varphi_1 - \frac{(p_1-p_2)}{L}) d\varphi_1$$

$$= \int_{\frac{p_1}{L}}^{\lambda_2+\frac{(p_1-p_2)}{L}} f_1(\varphi_1) F_2(\varphi_1 - \frac{(p_1-p_2)}{L}) d\varphi_1 + \int_{\lambda_2+\frac{(p_1-p_2)}{L}}^{\lambda_1} f_1(\varphi_1) F_2(\lambda_2) d\varphi_1$$

$$= Int_2(1, p_1, p_2, \lambda_2+\frac{(p_1-p_2)}{L}) + \int_{\lambda_2+\frac{(p_1-p_2)}{L}}^{\lambda_1} f_1(\varphi_1) d\varphi_1$$

$$= Int_2(1, p_1, p_2, \lambda_2+\frac{(p_1-p_2)}{L}) + F_1(\lambda_1) - F_1(\lambda_2+\frac{(p_1-p_2)}{L})$$

$$= 1 - F_1(\lambda_2+\frac{(p_1-p_2)}{L}) + Int_2(1, p_1, p_2, \lambda_2+\frac{(p_1-p_2)}{L})$$

o in summary;

$$_1 = \int_{\frac{p_1}{L}}^{\lambda_1} f_1(\varphi_1) F_2(\varphi_1 - \frac{(p_1-p_2)}{L}) d\varphi_1$$

$$= \begin{cases} Int_2(1, p_1, p_2, \lambda_1) & \text{if } \lambda_1 - \frac{(p_1-p_2)}{L} \le \lambda_2 \\ 1 - F_1(\lambda_2+\frac{(p_1-p_2)}{L}) + Int_2(1, p_1, p_2, \lambda_2+\frac{(p_1-p_2)}{L}) & \text{if } \lambda_1 - \frac{(p_1-p_2)}{L} > \lambda_2 \end{cases}$$

And by symmetry

$$= \int_{\frac{p_2}{L}}^{\lambda_2} f_2(\varphi_2) F_1(\varphi_2 + \frac{(p_1 - p_2)}{L}) d\varphi_2$$

$$= \begin{cases} \text{Int}_2(2, p_2, p_1, \lambda_2) & \text{if} \quad \lambda_2 + \frac{(p_1 - p_2)}{L} \leq \lambda_1 \\ 1 - F_1(\lambda_1 - \frac{(p_1 - p_2)}{L}) + \text{Int}_2(2, p_2, p_1, \lambda_1 - \frac{(p_1 - p_2)}{L}) & \text{if} \quad \lambda_2 + \frac{(p_1 - p_2)}{L} > \lambda_1 \end{cases}$$

ıe proportion of patients who choose to use neither drugs remains the same.

$$_{ND} = F_1(\frac{p_1}{L}) F_2(\frac{p_2}{L})$$

ppendix 5.2 The sensitivity of drug quantity to prices

ppendix 5.1 derived that the proportion of patients using drug 1 will be:

$$\mu_1 = \int_{\frac{p_1}{L}}^{\lambda_1} f_1(\varphi_1) F_2(\varphi_1 - \frac{(p_1 - p_2)}{L}) d\varphi_1$$

$$= \begin{cases} \text{Int}_2(1, p_1, p_2, \lambda_1) & \text{if} \quad \lambda_1 - \frac{(p_1 - p_2)}{L} \le \lambda_2 \\ 1 - F_1(\lambda_2 + \frac{(p_1 - p_2)}{L}) + \text{Int}_2(1, p_1, p_2, \lambda_2 + \frac{(p_1 - p_2)}{L}) & \text{if} \quad \lambda_1 - \frac{(p_1 - p_2)}{L} > \lambda_2 \end{cases}$$

aking each case in turn the effects of an increase in price of either drug can be determined.

ASE 1: $\lambda_1 - \frac{(p_1 - p_2)}{L} \le \lambda_2$, increase in p_1

$$_1 = \text{Int}_2(1, p_1, p_2, \lambda_1)$$

$$= \int_{\frac{p_1}{L}}^{\lambda_1} f_1(\varphi_1) F_2(\varphi_1 - \frac{(p_1 - p_2)}{L}) d\varphi_1$$

$$\frac{\partial \mu_1}{\partial p_1} = \frac{\partial}{\partial p_1} \int_{\frac{p_1}{L}}^{\lambda_1} f_1(\varphi_1) F_2(\varphi_1 - \frac{(p_1 - p_2)}{L}) d\varphi_1$$

$$= -\frac{1}{L} f_1(\frac{p_1}{L}) F_2(\frac{p_1}{L} - \frac{(p_1 - p_2)}{L}) + (-\frac{1}{L}) \int_{\frac{p_1}{L}}^{\lambda_1} f_1(\varphi_1) f_2(\varphi_1 - \frac{(p_1 - p_2)}{L}) d\varphi_1$$

$$= -\frac{1}{L} f_1(\frac{p_1}{L}) F_2(\frac{p_2}{L}) - \frac{1}{L} \text{Int}_1(1, p_1, p_2, \lambda_1)$$

$$= -\frac{\eta_1}{L}(\mu_N + \mu_1)$$

he two terms here represent the reduction in patients who face a worthwhile drug and the marginal hanges in drug choice where both drugs are at least treatment quality.

ASE 2: $\lambda_1 - \frac{(p_1 - p_2)}{L} > \lambda_2$, increase in p_1

$$_1 = 1 - F_1(\lambda_2 + \frac{(p_1 - p_2)}{L}) + \text{Int}_2(1, p_1, p_2, \lambda_2 + \frac{(p_1 - p_2)}{L})$$

$$= 1 - F_1(\lambda_2 + \frac{(p_1 - p_2)}{L}) + \int_{\frac{p_1}{L}}^{\lambda_2 + \frac{(p_1 - p_2)}{L}} f_1(\varphi_1) F_2(\varphi_1 - \frac{(p_1 - p_2)}{L}) d\varphi_1$$

$$\frac{\partial \mu_1}{\partial p_1} = \frac{\partial}{\partial p_1} \left[1 - F_1(\lambda_2 + \frac{(p_1 - p_2)}{L}) + \int_{\frac{p_1}{L}}^{\lambda_2 + \frac{(p_1 - p_2)}{L}} f_1(\varphi_1) F_2(\varphi_1 - \frac{(p_1 - p_2)}{L}) d\varphi_1 \right]$$

$$= 0 - \frac{1}{L} f_1(\lambda_2 + \frac{(p_1 - p_2)}{L}) + \frac{1}{L} f_1(\lambda_2 + \frac{(p_1 - p_2)}{L}) F_2(\lambda_2 + \frac{(p_1 - p_2)}{L} - \frac{(p_1 - p_2)}{L})$$

$$- \frac{1}{L} f_1(\frac{p_1}{L}) F_2(\frac{p_1}{L} - \frac{(p_1 - p_2)}{L}) - \frac{1}{L} \int_{\frac{p_1}{L}}^{\lambda_2 + \frac{(p_1 - p_2)}{L}} f_1(\varphi_1) f_2(\varphi_1 - \frac{(p_1 - p_2)}{L}) d\varphi_1$$

$$= -\tfrac{1}{L} f_1(\lambda_2 + \frac{(p_1 - p_2)}{L}) + \tfrac{1}{L} f_1(\lambda_2 + \tfrac{(p_1 - p_2)}{L}) F_2(\lambda_2)$$
$$- \tfrac{1}{L} f_1(\tfrac{p_1}{L}) F_2(\tfrac{p_2}{L}) - \tfrac{1}{L} \mathrm{Int}_1(I, p_1, p_2, \lambda_2 + \tfrac{(p_1 - p_2)}{L})$$
$$= -\tfrac{1}{L} f_1(\lambda_2 + \frac{(p_1 - p_2)}{L}) + \tfrac{1}{L} f_1(\lambda_2 + \tfrac{(p_1 - p_2)}{L}) - \tfrac{1}{L} f_1(\tfrac{p_1}{L}) F_2(\tfrac{p_2}{L}) - \tfrac{1}{L} \mathrm{Int}_1(I, p_1, p_2, \lambda_2 + \tfrac{(p_1 - p_2)}{L})$$
$$= -\tfrac{1}{L} f_1(\tfrac{p_1}{L}) F_2(\tfrac{p_2}{L}) - \tfrac{1}{L} \mathrm{Int}_1(I, p_1, p_2, \lambda_2 + \tfrac{(p_1 - p_2)}{L})$$
$$= -\tfrac{\eta_1}{L} \mu_N - \tfrac{\eta_1}{L} \mathrm{Int}_2(I, p_1, p_2, \lambda_2 + \tfrac{(p_1 - p_2)}{L})$$
$$= -\tfrac{\eta_1}{L} \mu_N - \tfrac{\eta_1}{L} (\mu_1 - (1 - F_1(\lambda_2 + \frac{(p_1 - p_2)}{L}))$$
$$- \tfrac{\eta_1}{L} (\mu_N + \mu_1 - (1 - F_1(\lambda_2 + \frac{(p_1 - p_2)}{L}))$$

with the earlier case the two terms represent the reduction in market size and marginal changes in ıg choice.

ASE 3: $\lambda_1 - \frac{(p_1 - p_2)}{L} \le \lambda_2$, increase in p_2

$$= \mathrm{Int}_2(I, p_1, p_2, \lambda_1)$$

$$\frac{\partial}{\partial p_2} = \frac{\partial}{\partial p_2} \mathrm{Int}_2(I, p_1, p_2, \lambda_1)$$
$$= \frac{\partial}{\partial p_2} \int_{\frac{p_1}{L}}^{\lambda_1} f_1(\varphi_1) F_2(\varphi_1 - \frac{(p_1 - p_2)}{L}) d\varphi_1$$
$$= \frac{\partial}{\partial p_2} \int_{\frac{p_1}{L}}^{\lambda_1} f_1(\varphi_1) e^{\eta_2(\varphi_1 - \frac{(p_1 - p_2)}{L} - \lambda_2)} d\varphi_1$$
$$= \frac{\eta_2}{L} \int_{\frac{p_1}{L}}^{\lambda_1} f_1(\varphi_1) e^{\eta_2(\varphi_1 - \frac{(p_1 - p_2)}{L} - \lambda_2)} d\varphi_1$$
$$= \frac{\eta_2}{L} \mu_1$$

n increase in the price of firm 2 increases the quantity of firm 1 proportionately.

ASE 4: $\lambda_1 - \frac{(p_1 - p_2)}{L} > \lambda_2$, increase in p_2

$$= 1 - F_1(\lambda_2 + \frac{(p_1 - p_2)}{L}) + \mathrm{Int}_2(I, p_1, p_2, \lambda_2 + \frac{(p_1 - p_2)}{L})$$

$$\frac{\partial}{\partial p_2} = \frac{\partial}{\partial p_2} (1 - F_1(\lambda_2 + \frac{(p_1 - p_2)}{L}) + \mathrm{Int}_2(I, p_1, p_2, \lambda_2 + \frac{(p_1 - p_2)}{L}))$$
$$= -\frac{\partial}{\partial p_2} F_1(\lambda_2 + \frac{(p_1 - p_2)}{L}) + \frac{\partial}{\partial p_2} \mathrm{Int}_2(I, p_1, p_2, \lambda_2 + \frac{(p_1 - p_2)}{L})$$
$$= -\frac{\partial}{\partial p_2} e^{\eta_1(\lambda_2 + \frac{(p_1 - p_2)}{L} - \lambda_1)} + \frac{\partial}{\partial p_2} \int_{\frac{p_1}{L}}^{\lambda_2 + \frac{(p_1 - p_2)}{L}} f_1(\varphi_1) F_2(\varphi_1 - \frac{(p_1 - p_2)}{L}) d\varphi_1$$
$$= \frac{\eta_1}{L} e^{\eta_1(\lambda_2 + \frac{(p_1 - p_2)}{L} - \lambda_1)} - \frac{1}{L} f_1(\lambda_2 + \tfrac{(p_1 - p_2)}{L}) F_2(\lambda_2 + \tfrac{(p_1 - p_2)}{L} - \frac{(p_1 - p_2)}{L})$$
$$+ \int_{\frac{p_1}{L}}^{\lambda_2 + \frac{(p_1 - p_2)}{L}} f_1(\varphi_1) \frac{\partial}{\partial p_2} F_2(\varphi_1 - \frac{(p_1 - p_2)}{L}) d\varphi_1$$

$$= \frac{\eta_1}{L} F_1(\lambda_2 + \frac{(p_1 - p_2)}{L}) - \frac{\eta_1}{L} F_1(\lambda_2 + \frac{(p_1 - p_2)}{L}) F_2(\lambda_2) + \int_{\frac{p_1}{L}}^{\lambda_2 + \frac{(p_1 - p_2)}{L}} f_1(\varphi_1) \frac{\partial}{\partial p_2} F_2(\varphi_1 - \frac{(p_1 - p_2)}{L}) d\varphi_1$$

$$= \int_{\frac{p_1}{L}}^{\lambda_2 + \frac{(p_1 - p_2)}{L}} f_1(\varphi_1) \frac{\partial}{\partial p_2} F_2(\varphi_1 - \frac{(p_1 - p_2)}{L}) d\varphi_1$$

$$= \int_{\frac{p_1}{L}}^{\lambda_2 + \frac{(p_1 - p_2)}{L}} f_1(\varphi_1) \frac{\partial}{\partial p_2} e^{\eta_2(\varphi_1 - \frac{(p_1 - p_2)}{L} - \lambda_2)} d\varphi_1$$

$$= \frac{\eta_2}{L} \int_{\frac{p_1}{L}}^{\lambda_2 + \frac{(p_1 - p_2)}{L}} f_1(\varphi_1) e^{\eta_2(\varphi_1 - \frac{(p_1 - p_2)}{L} - \lambda_2)} d\varphi_1$$

$$= \frac{\eta_2}{L} \int_{\frac{p_1}{L}}^{\lambda_2 + \frac{(p_1 - p_2)}{L}} f_1(\varphi_1) F_2(\varphi_1 - \frac{(p_1 - p_2)}{L}) d\varphi_1$$

$$= \frac{\eta_2}{L} (\mu_1 - (1 - F_1(\lambda_2 + \frac{(p_1 - p_2)}{L}))$$

summary:

$$\frac{1}{1} = \begin{cases} -\frac{\eta_1}{L}(\mu_N + \mu_1) & \text{if} \quad \lambda_1 - \frac{(p_1 - p_2)}{L} \le \lambda_2 \\ -\frac{\eta_1}{L}(\mu_N + \mu_1 - (1 - F_1(\lambda_2 + \frac{(p_1 - p_2)}{L})) & \text{if} \quad \lambda_1 - \frac{(p_1 - p_2)}{L} > \lambda_2 \end{cases}$$

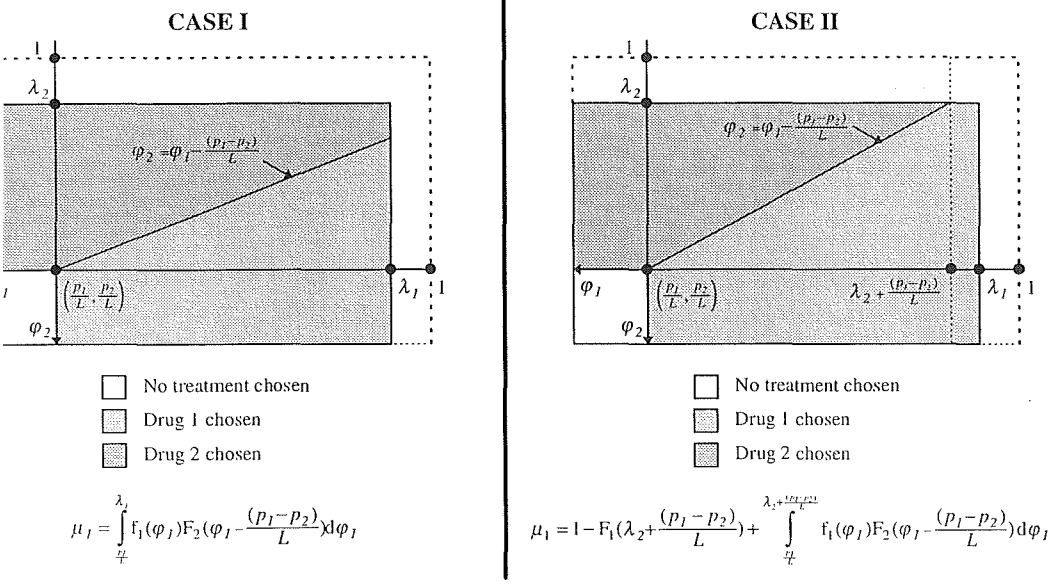
$$\frac{1}{2} = \begin{cases} \frac{\eta_2}{L}\mu_1 & \text{if} \quad \lambda_1 - \frac{(p_1 - p_2)}{L} \le \lambda_2 \\ \frac{\eta_2}{L}(\mu_1 - (1 - F_1(\lambda_2 + \frac{(p_1 - p_2)}{L})) & \text{if} \quad \lambda_1 - \frac{(p_1 - p_2)}{L} > \lambda_2 \end{cases}$$

ppendix 6.1 Consumer surplus in the no search model

Appendix 5.1, where the proportion of patients using each drug was defined, it was necessary to stinguish between two cases. These cases were:

CASE I: $\lambda_1 - \frac{(p_1 - p_2)}{L} \leq \lambda_2$. The quantity consumed is a simple integral. In the picture corresponding to the two shares this case (for drug 1) is represented by the line of marginal consumers cutting the right edge of the box.

CASE II: $\lambda_1 - \frac{(p_1 - p_2)}{L} > \lambda_2$. The quantity consumed is the sum of a probability and a simple integral. In the picture corresponding to the two shares this case (for drug 1) is represented by the line of marginal consumers cutting the top edge of the box.



$$\mu_1 = \int_{\frac{p_1}{L}}^{\lambda_1} f_1(\varphi_1) F_2(\varphi_1 - \frac{(p_1 - p_2)}{L}) d\varphi_1$$

$$\mu_1 = 1 - F_1(\lambda_2 + \frac{(p_1 - p_2)}{L}) + \int_{\frac{p_1}{L}}^{\lambda_2 + \frac{(p_1 - p_2)}{L}} f_1(\varphi_1) F_2(\varphi_1 - \frac{(p_1 - p_2)}{L}) d\varphi_1$$

o proceed it is necessary to retain these cases and formulate a definition for consumer surplus in a ecewise fashion. Before separating the cases it is worthwhile to first define two lemmas that are quired in each case.

emma I: Utility above the non-treatment level

onsumer surplus is the measure of the difference between the aggregate willingness to pay of patients nd the total cost they incur by them. This requires a definition of the willingness of a single patient to ay.

has previously been assumed that the utility function of a patient, under a no search model is of the rm:

$$U = m - pq - L(1 - \varphi\sqrt{q}).$$

No treatment (base) utility is $U_0 = m - L$.

Where treatment is selected, utility is

$$\begin{aligned} U_1(\varphi_1) &= m - p - L(1 - \varphi) \\ &= m - p - L + L\varphi \\ &= (m - L) - p + L\varphi \\ &= U_0 + L\varphi - p. \end{aligned}$$

The difference between the treatment and no treatment levels of utility is therefore

$$U_1(\varphi_1) - U_0 = L\varphi - p.$$

emma II: Evaluation of $\int_{\frac{p_1}{L}}^{B} \varphi_1 f_1(\varphi_1) F_2(\varphi_1 - \frac{(p_1 - p_2)}{L}) d\varphi_1$

$$\int_{\frac{p_1}{L}}^{\lambda_1} \varphi_1 f_1(\varphi_1) F_2(\varphi_1 - \frac{(p_1-p_2)}{L}) d\varphi_1$$

and after expanding out the exponential terms

$$= \int_{\frac{p_1}{L}}^{B} \varphi_1 \left(\eta_1 e^{\eta_1(\varphi_1-\lambda_1)}\right)\left(e^{\eta_2(\varphi_1-\frac{(p_1-p_2)}{L}-\lambda_2)}\right) d\varphi_1$$

bringing all constant terms outside the integral

$$= \eta_1 e^{-\eta_1\lambda_1-\eta_2(\frac{(p_1-p_2)}{L}+\lambda_2)} \int_{\frac{p_1}{L}}^{B} \varphi_1 e^{(\eta_1+\eta_2)\varphi_1} d\varphi_1$$

now since $\int Axe^{Bx}dx = \frac{A}{B}(x-\frac{1}{B})e^{Bx} + C$

$$= \eta_1 e^{-\eta_1\lambda_1-\eta_2(\frac{(p_1-p_2)}{L}+\lambda_2)} \left[\frac{1}{\eta_1+\eta_2}\left(\varphi_1 - \frac{1}{\eta_1+\eta_2}\right)e^{(\eta_1+\eta_2)\varphi_1}\right]_{\frac{p_1}{L}}^{B}$$

after reincorporating constants the expression becomes

$$= \frac{1}{\eta_1+\eta_2}\left[\eta_1\left(\varphi_1 - \frac{1}{\eta_1+\eta_2}\right)e^{-\eta_1\lambda_1-\eta_2(\frac{(p_1-p_2)}{L}+\lambda_2)}e^{(\eta_1+\eta_2)\varphi_1}\right]_{\frac{p_1}{L}}^{B}$$

and after grouping η_i terms

$$= \frac{1}{\eta_1+\eta_2}\left[\left(\varphi_1 - \frac{1}{\eta_1+\eta_2}\right)\left(\eta_1 e^{\eta_1(\varphi_1-\lambda_1)}\right)\left(e^{\eta_2(\varphi_1-\frac{(p_1-p_2)}{L}-\lambda_2)}\right)\right]_{\frac{p_1}{L}}^{B}$$

the expression can be re-written using the density functions

$$= \frac{1}{\eta_1+\eta_2}\left[\left(\varphi_1 - \frac{1}{\eta_1+\eta_2}\right)f_1(\varphi_1)F_2(\varphi_1-\frac{(p_1-p_2)}{L})\right]_{\frac{p_1}{L}}^{B}$$

evaluating at the integral endpoints we find

$$= \frac{1}{\eta_1+\eta_2}\left[\left(B-\frac{1}{\eta_1+\eta_2}\right)f_1(B)F_2(B-\frac{(p_1-p_2)}{L}) - \left(\frac{p_1}{L}-\frac{1}{\eta_1+\eta_2}\right)f_1(\frac{p_1}{L})F_2(\frac{p_1}{L}-\frac{(p_1-p_2)}{L})\right]$$

$$= \frac{1}{\eta_1+\eta_2}\left[\left(B-\frac{1}{\eta_1+\eta_2}\right)f_1(B)F_2(B-\frac{(p_1-p_2)}{L}) - \left(\frac{p_1}{L}-\frac{1}{\eta_1+\eta_2}\right)f_1(\frac{p_1}{L})F_2(\frac{p_2}{L})\right]$$

and on expansion this becomes

$$\frac{B}{\eta_1+\eta_2}f_1(B)F_2(B-\frac{(p_1-p_2)}{L}) - \frac{1}{\eta_1+\eta_2}\frac{p_1}{L}f_1(\frac{p_1}{L})F_2(\frac{p_2}{L})$$
$$-\frac{1}{\eta_1+\eta_2}\left[\frac{1}{\eta_1+\eta_2}f_1(B)F_2(B-\frac{(p_1-p_2)}{L}) - \frac{1}{\eta_1+\eta_2}f_1(\frac{p_1}{L})F_2(\frac{p_2}{L})\right]$$

which, from Appendix 2.2, is

$$\frac{B}{\eta_1+\eta_2}f_1(B)F_2(B-\frac{(p_1-p_2)}{L}) - \frac{1}{\eta_1+\eta_2}\frac{p_1}{L}f_1(\frac{p_1}{L})F_2(\frac{p_2}{L}) - \frac{1}{\eta_1+\eta_2}\int_{\frac{p_1}{L}}^{B} f_1(\varphi_1)F_2(\varphi_1-\frac{(p_1-p_2)}{L})d\varphi_1$$

CASE I: $\lambda_1 - \frac{(p_1-p_2)}{L} \le \lambda_2$

The quantity of drug 1, μ_1, was derived in Appendix 5.1 and takes the value $\int_{\frac{p_1}{L}}^{\lambda_1} f_1(\varphi_1)F_2(\varphi_1-\frac{(p_1-p_2)}{L})d\varphi_1$.

The value of consumer surplus is the excess willingness to pay weighted by the likelihood of drug 1 being used. The consumer surplus associated with drug 1 is:

$$CS_1 = \int_{\frac{p_1}{L}}^{\lambda_1} f_1(\varphi_1)F_2(\varphi_1-\frac{(p_1-p_2)}{L})\left[U_1(\varphi_1) - U_0\right]d\varphi_1$$

$$= \int_{\frac{p_1}{L}}^{\lambda_1} f_1(\varphi_1)F_2(\varphi_1-\frac{(p_1-p_2)}{L})\left[L\varphi_1 - p_1\right]d\varphi_1$$

(Lemma I)

$$L\int_{\frac{p_1}{L}}^{\lambda_1} \varphi_1 f_1(\varphi_1)F_2(\varphi_1-\frac{(p_1-p_2)}{L})d\varphi_1 - p_1\int_{\frac{p_1}{L}}^{\lambda_1} f_1(\varphi_1)F_2(\varphi_1-\frac{(p_1-p_2)}{L})d\varphi_1$$

$$L\int_{\frac{p_1}{L}}^{\lambda_1}\varphi_1 f_1(\varphi_1)F_2(\varphi_1-\tfrac{(p_1-p_2)}{L})d\varphi_1 - p_1\mu_1$$

$$L\left[\frac{B}{\eta_1+\eta_2}f_1(B)F_2(B-\tfrac{(p_1-p_2)}{L})-\frac{1}{\eta_1+\eta_2}\frac{p_1}{L}f_1(\tfrac{p_1}{L})F_2(\tfrac{p_2}{L})-\frac{1}{\eta_1+\eta_2}\int_{\frac{p_1}{L}}^{B}f_1(\varphi_1)F_2(\varphi_1-\tfrac{(p_1-p_2)}{L})d\varphi_1\right]_{\text{at } B=\lambda_1} - p_1\mu_1$$

(Lemma II)

$$L\left[\frac{\lambda_1}{\eta_1+\eta_2}f_1(\lambda_1)F_2(\lambda_1-\tfrac{(p_1-p_2)}{L})-\frac{1}{\eta_1+\eta_2}\frac{p_1}{L}f_1(\tfrac{p_1}{L})F_2(\tfrac{p_2}{L})-\frac{1}{\eta_1+\eta_2}\int_{\frac{p_1}{L}}^{\lambda_1}f_1(\varphi_1)F_2(\varphi_1-\tfrac{(p_1-p_2)}{L})d\varphi_1\right]-p_1\mu_1$$

$$L\left[\frac{\lambda_1}{\eta_1+\eta_2}f_1(\lambda_1)F_2(\lambda_1-\tfrac{(p_1-p_2)}{L})-\frac{1}{\eta_1+\eta_2}\frac{p_1}{L}f_1(\tfrac{p_1}{L})F_2(\tfrac{p_2}{L})-\frac{1}{\eta_1+\eta_2}\mu_1\right]-p_1\mu_1$$

$$\frac{L\lambda_1}{\eta_1+\eta_2}f_1(\lambda_1)F_2(\lambda_1-\tfrac{(p_1-p_2)}{L})-\frac{L}{\eta_1+\eta_2}\frac{p_1}{L}f_1(\tfrac{p_1}{L})F_2(\tfrac{p_2}{L})-(p_1+\tfrac{L}{\eta_1+\eta_2})\mu_1$$

$$\frac{L\eta_1\lambda_1}{\eta_1+\eta_2}F_2(\lambda_1-\tfrac{(p_1-p_2)}{L})-\frac{L}{\eta_1+\eta_2}\frac{p_1}{L}f_1(\tfrac{p_1}{L})F_2(\tfrac{p_2}{L})-(p_1+\tfrac{L}{\eta_1+\eta_2})\mu_1$$

since $f_1(\lambda_1)=\eta_1F_1(\lambda_1)=\eta_1$

CASE II: $\lambda_1-\dfrac{(p_1-p_2)}{L}>\lambda_2$

In this case the expression for the quantity of drug 1 is slightly more complicated than in the earlier case. In Appendix 5.1 the value of μ_1 was derived to be the following:

$$\mu_1 = 1-F_1(\lambda_2+\frac{(p_1-p_2)}{L})+\int_{\frac{p_1}{L}}^{\lambda_2+\frac{(p_1-p_2)}{L}}f_1(\varphi_1)F_2(\varphi_1-\frac{(p_1-p_2)}{L})d\varphi_1$$

$$=1-F_1(\lambda_2+\frac{(p_1-p_2)}{L})+\frac{1}{\eta_1+\eta_2}\left[f_1(\lambda_2+\tfrac{(p_1-p_2)}{L})F_2(\lambda_2)-f_1(\tfrac{p_1}{L})F_2(\tfrac{p_2}{L})\right]$$

$$=1-F_1(\lambda_2+\frac{(p_1-p_2)}{L})+\frac{1}{\eta_1+\eta_2}\left[f_1(\lambda_2+\tfrac{(p_1-p_2)}{L})-f_1(\tfrac{p_1}{L})F_2(\tfrac{p_2}{L})\right]$$

Now as before the value of consumer surplus is the integral of the product of increased utility and the likelihood of purchase for each value of φ_1.

$$\int_{\frac{p_1}{L}}^{\lambda_1}f_1(\varphi_1)F_2(\varphi_1-\tfrac{(p_1-p_2)}{L})\left[U_1(\varphi_1)-U_0\right]d\varphi_1$$

$$=\int_{\frac{p_1}{L}}^{\lambda_1}f_1(\varphi_1)F_2(\varphi_1-\tfrac{(p_1-p_2)}{L})\left[L\varphi_1-p_1\right]d\varphi_1$$

(Lemma I)

$$=L\int_{\frac{p_1}{L}}^{\lambda_1}\varphi_1 f_1(\varphi_1)F_2(\varphi_1-\tfrac{(p_1-p_2)}{L})d\varphi_1 - p_1\int_{\frac{p_1}{L}}^{\lambda_1}f_1(\varphi_1)F_2(\varphi_1-\tfrac{(p_1-p_2)}{L})d\varphi_1$$

$$=L\int_{\lambda_2+\frac{(p_1-p_2)}{L}}^{\lambda_1}\varphi_1 f_1(\varphi_1)F_2(\lambda_2)d\varphi_1+L\int_{\frac{p_1}{L}}^{\lambda_2+\frac{(p_1-p_2)}{L}}\varphi_1 f_1(\varphi_1)F_2(\varphi_1-\tfrac{(p_1-p_2)}{L})d\varphi_1-p_1\mu_1$$

$$=L\int_{\lambda_2+\frac{(p_1-p_2)}{L}}^{\lambda_1}\varphi_1 f_1(\varphi_1)d\varphi_1+L\int_{\frac{p_1}{L}}^{\lambda_2+\frac{(p_1-p_2)}{L}}\varphi_1 f_1(\varphi_1)F_2(\varphi_1-\tfrac{(p_1-p_2)}{L})d\varphi_1-p_1\mu_1$$

To proceed it is worthwhile to evaluate the first term separately. From Lemma II there is already a relatively simple expression for the second term while the third term is already in its simplest form.

$$\int_{\lambda_2+\frac{(p_1-p_2)}{L}}^{\lambda_1} \varphi_1 f_1(\varphi_1)\mathrm{d}\varphi_1$$

$$L\int_{\lambda_2+\frac{(p_1-p_2)}{L}}^{\lambda_1} \eta_1\varphi_1 e^{\eta_1(\varphi_1-\lambda_1)}\mathrm{d}\varphi_1$$

and since $\int Axe^{Bx}\mathrm{d}x = \frac{A}{B}(x-\frac{1}{B})e^{Bx}+C$

$$\left[L\frac{\eta_1}{\eta_1}(\varphi_1-\frac{1}{\eta_1})e^{\eta_1(\varphi_1-\lambda_1)}\right]_{\lambda_2+\frac{(p_1-p_2)}{L}}^{\lambda_1}$$

$$\left[L(\varphi_1-\frac{1}{\eta_1})F_1(\varphi_1)\right]_{\lambda_2+\frac{(p_1-p_2)}{L}}^{\lambda_1}$$

after evaluating at the endpoints

$$\left[L(\lambda_1-\frac{1}{\eta_1})F_1(\lambda_1)-L(\lambda_2+\frac{(p_1-p_2)}{L}-\frac{1}{\eta_1})F_1(\lambda_2+\frac{(p_1-p_2)}{L})\right]$$

$$L(\lambda_1-\frac{1}{\eta_1})-L(\lambda_2+\frac{(p_1-p_2)}{L}-\frac{1}{\eta_1})F_1(\lambda_2+\frac{(p_1-p_2)}{L})$$

ne second term in the consumer surplus equation is:

$$\int_{\frac{p_1}{L}}^{\lambda_2+\frac{(p_1-p_2)}{L}} \varphi_1 f_1(\varphi_1)F_2(\varphi_1-\frac{(p_1-p_2)}{L})\mathrm{d}\varphi_1$$

(Lemma II)

$$L\left[\frac{B}{\eta_1+\eta_2}f_1(B)F_2(B-\frac{(p_1-p_2)}{L})-\frac{1}{\eta_1+\eta_2}\frac{p_1}{L}f_1(\frac{p_1}{L})F_2(\frac{p_2}{L})-\frac{1}{\eta_1+\eta_2}\int_{\frac{p_1}{L}}^{B} f_1(\varphi_1)F_2(\varphi_1-\frac{(p_1-p_2)}{L})\mathrm{d}\varphi_1\right]_{B=\lambda_2+\frac{(p_1-p_2)}{L}}$$

evaluating this expression we get

$$L[\frac{\left(\lambda_2+\frac{(p_1-p_2)}{L}\right)}{\eta_1+\eta_2}f_1(\lambda_2+\frac{(p_1-p_2)}{L})F_2(\lambda_2+\frac{(p_1-p_2)}{L}-\frac{(p_1-p_2)}{L})-\frac{1}{\eta_1+\eta_2}\frac{p_1}{L}f_1(\frac{p_1}{L})F_2(\frac{p_2}{L})$$

$$-\frac{1}{\eta_1+\eta_2}\int_{\frac{p_1}{L}}^{\lambda_2+\frac{(p_1-p_2)}{L}} f_1(\varphi_1)F_2(\varphi_1-\frac{(p_1-p_2)}{L})\mathrm{d}\varphi_1]$$

$$L[\frac{\left(\lambda_2+\frac{(p_1-p_2)}{L}\right)}{\eta_1+\eta_2}f_1(\lambda_2+\frac{(p_1-p_2)}{L})F_2(\lambda_2)-\frac{1}{\eta_1+\eta_2}\frac{p_1}{L}f_1(\frac{p_1}{L})F_2(\frac{p_2}{L})-\frac{1}{\eta_1+\eta_2}\int_{\frac{p_1}{L}}^{\lambda_2+\frac{(p_1-p_2)}{L}} f_1(\varphi_1)F_2(\varphi_1-\frac{(p_1-p_2)}{L})\mathrm{d}\varphi_1]$$ from the

pression for μ_1 above

$$L[\frac{\left(\lambda_2+\frac{(p_1-p_2)}{L}\right)}{\eta_1+\eta_2}f_1(\lambda_2+\frac{(p_1-p_2)}{L})-\frac{1}{\eta_1+\eta_2}\frac{p_1}{L}f_1(\frac{p_1}{L})F_2(\frac{p_2}{L})-\frac{1}{\eta_1+\eta_2}(\mu_1-(1-F_1(\lambda_2+\frac{(p_1-p_2)}{L}))]$$

$$\frac{L}{\eta_1+\eta_2}[\left(\lambda_2+\frac{(p_1-p_2)}{L}\right)f_1(\lambda_2+\frac{(p_1-p_2)}{L})-\frac{p_1}{L}f_1(\frac{p_1}{L})F_2(\frac{p_2}{L})-\mu_1+1-F_1(\lambda_2+\frac{(p_1-p_2)}{L})]$$

ombining the three terms we get:

$$S_1 = L(\lambda_1-\frac{1}{\eta_1})-L(\lambda_2+\frac{(p_1-p_2)}{L}-\frac{1}{\eta_1})F_1(\lambda_2+\frac{(p_1-p_2)}{L})$$

$$+\frac{L}{\eta_1+\eta_2}[\left(\lambda_2+\frac{(p_1-p_2)}{L}\right)f_1(\lambda_2+\frac{(p_1-p_2)}{L})-\frac{p_1}{L}f_1(\frac{p_1}{L})F_2(\frac{p_2}{L})-\mu_1+1-F_1(\lambda_2+\frac{(p_1-p_2)}{L})]$$

$$-p_1\mu_1$$

$$L(\lambda_1-\frac{1}{\eta_1})-L(\lambda_2+\frac{(p_1-p_2)}{L}-\frac{1}{\eta_1})F_1(\lambda_2+\frac{(p_1-p_2)}{L})$$

$$+\frac{L}{\eta_1+\eta_2}[\eta_1\left(\lambda_2+\frac{(p_1-p_2)}{L}\right)F_1(\lambda_2+\frac{(p_1-p_2)}{L})-\frac{p_1}{L}f_1(\frac{p_1}{L})F_2(\frac{p_2}{L})-\mu_1+1-F_1(\lambda_2+\frac{(p_1-p_2)}{L})]$$

$$-p_1\mu_1$$

since $f_1(x)=\eta_1F_1(x)$

$$L(\lambda_1-\tfrac{1}{\eta_1})-L(\lambda_2+\tfrac{(p_1-p_2)}{L}-\tfrac{1}{\eta_1})\mathrm{F}_1(\lambda_2+\tfrac{(p_1-p_2)}{L})$$
$$+\tfrac{\eta_1 L}{\eta_1+\eta_2}\Big(\lambda_2+\tfrac{(p_1-p_2)}{L}\Big)\mathrm{F}_1(\lambda_2+\tfrac{(p_1-p_2)}{L})-\tfrac{L}{\eta_1+\eta_2}\tfrac{p_1}{L}\mathrm{f}_1(\tfrac{p_1}{L})\mathrm{F}_2(\tfrac{p_2}{L})$$
$$-\tfrac{L}{\eta_1+\eta_2}\mu_1+\tfrac{L}{\eta_1+\eta_2}1-\tfrac{L}{\eta_1+\eta_2}\mathrm{F}_1(\lambda_2+\tfrac{(p_1-p_2)}{L})$$
$$-p_1\mu_1$$

and after rearranging to isolate terms involving $\mathrm{F}_1(\lambda_2+\frac{(p_1-p_2)}{L})$

$$L(\lambda_1-\tfrac{1}{\eta_1})-p_1\mu_1-\tfrac{L}{\eta_1+\eta_2}\tfrac{p_1}{L}\mathrm{f}_1(\tfrac{p_1}{L})\mathrm{F}_2(\tfrac{p_2}{L})+\tfrac{L}{\eta_1+\eta_2}1-\tfrac{L}{\eta_1+\eta_2}\mu_1$$
$$+\tfrac{\eta_1 L}{\eta_1+\eta_2}\Big(\lambda_2+\tfrac{(p_1-p_2)}{L}\Big)\mathrm{F}_1(\lambda_2+\tfrac{(p_1-p_2)}{L})-\tfrac{L}{\eta_1+\eta_2}\mathrm{F}_1(\lambda_2+\tfrac{(p_1-p_2)}{L})$$
$$-L(\lambda_2+\tfrac{(p_1-p_2)}{L}-\tfrac{1}{\eta_1})\mathrm{F}_1(\lambda_2+\tfrac{(p_1-p_2)}{L})$$

and grouping terms involving $\mathrm{F}_1(\lambda_2+\frac{(p_1-p_2)}{L})$

$$L(\lambda_1-\tfrac{1}{\eta_1})+\tfrac{L}{\eta_1+\eta_2}-\Big(p_1+\tfrac{L}{\eta_1+\eta_2}\Big)\mu_1-\tfrac{L}{\eta_1+\eta_2}\tfrac{p_1}{L}\mathrm{f}_1(\tfrac{p_1}{L})\mathrm{F}_2(\tfrac{p_2}{L})$$
$$+\mathrm{F}_1(\lambda_2+\tfrac{(p_1-p_2)}{L})[\tfrac{\eta_1 L}{\eta_1+\eta_2}\lambda_2+\tfrac{\eta_1 L}{\eta_1+\eta_2}\tfrac{(p_1-p_2)}{L}-\tfrac{L}{\eta_1+\eta_2}-L(\lambda_2+\tfrac{(p_1-p_2)}{L}-\tfrac{1}{\eta_1})]$$

taking $\frac{L}{\eta_1+\eta_2}$ outside the brackets allows for a simpler cancellation

$$L(\lambda_1-\tfrac{1}{\eta_1})+\tfrac{L}{\eta_1+\eta_2}-\Big(p_1+\tfrac{L}{\eta_1+\eta_2}\Big)\mu_1-\tfrac{L}{\eta_1+\eta_2}\tfrac{p_1}{L}\mathrm{f}_1(\tfrac{p_1}{L})\mathrm{F}_2(\tfrac{p_2}{L})$$
$$+\tfrac{L}{\eta_1+\eta_2}\mathrm{F}_1(\lambda_2+\tfrac{(p_1-p_2)}{L})[\eta_1\lambda_2+\eta_1\tfrac{(p_1-p_2)}{L}-1-(\eta_1+\eta_2)(\lambda_2+\tfrac{(p_1-p_2)}{L}-\tfrac{1}{\eta_1})]$$
$$L(\lambda_1-\tfrac{1}{\eta_1})+\tfrac{L}{\eta_1+\eta_2}-\Big(p_1+\tfrac{L}{\eta_1+\eta_2}\Big)\mu_1-\tfrac{L}{\eta_1+\eta_2}\tfrac{p_1}{L}\mathrm{f}_1(\tfrac{p_1}{L})\mathrm{F}_2(\tfrac{p_2}{L})$$
$$+\tfrac{L}{\eta_1+\eta_2}\mathrm{F}_1(\lambda_2+\tfrac{(p_1-p_2)}{L})[\eta_1(\lambda_2+\tfrac{(p_1-p_2)}{L}-\tfrac{1}{\eta_1})-(\eta_1+\eta_2)(\lambda_2+\tfrac{(p_1-p_2)}{L}-\tfrac{1}{\eta_1})]$$
$$L(\lambda_1-\tfrac{1}{\eta_1})+\tfrac{L}{\eta_1+\eta_2}-\Big(p_1+\tfrac{L}{\eta_1+\eta_2}\Big)\mu_1-\tfrac{L}{\eta_1+\eta_2}\tfrac{p_1}{L}\mathrm{f}_1(\tfrac{p_1}{L})\mathrm{F}_2(\tfrac{p_2}{L})$$
$$-\tfrac{\eta_2 L}{\eta_1+\eta_2}\mathrm{F}_1(\lambda_2+\tfrac{(p_1-p_2)}{L})[\lambda_2+\tfrac{(p_1-p_2)}{L}-\tfrac{1}{\eta_1}]$$

his last expression appears to be the simplest form in which consumer surplus can be expressed. In ımmary then for drug 1:

$$S_1=\begin{cases}\tfrac{L\eta_1\lambda_1}{\eta_1+\eta_2}\mathrm{F}_2(\lambda_1-\tfrac{(p_1-p_2)}{L})-\tfrac{L}{\eta_1+\eta_2}\tfrac{p_1}{L}\mathrm{f}_1(\tfrac{p_1}{L})\mathrm{F}_2(\tfrac{p_2}{L})-(p_1+\tfrac{L}{\eta_1+\eta_2})\mu_1 & \text{where } \lambda_1-\tfrac{(p_1-p_2)}{L}\le\lambda_2\\ L(\lambda_1-\tfrac{1}{\eta_1})+\tfrac{L}{\eta_1+\eta_2}-\Big(p_1+\tfrac{L}{\eta_1+\eta_2}\Big)\mu_1-\tfrac{L}{\eta_1+\eta_2}\tfrac{p_1}{L}\mathrm{f}_1(\tfrac{p_1}{L})\mathrm{F}_2(\tfrac{p_2}{L}) & \\ \quad -\tfrac{\eta_2 L}{\eta_1+\eta_2}\mathrm{F}_1(\lambda_2+\tfrac{(p_1-p_2)}{L})[\lambda_2+\tfrac{(p_1-p_2)}{L}-\tfrac{1}{\eta_1}] & \text{where } \lambda_1-\tfrac{(p_1-p_2)}{L}>\lambda_2\end{cases}$$

y symmetry we can also find the consumer surplus for drug 2:

$$S_2=\begin{cases}L(\lambda_2-\tfrac{1}{\eta_2})+\tfrac{L}{\eta_1+\eta_2}-\Big(p_2+\tfrac{L}{\eta_1+\eta_2}\Big)\mu_2-\tfrac{L}{\eta_1+\eta_2}\tfrac{p_2}{L}\mathrm{F}_1(\tfrac{p_1}{L})\mathrm{f}_2(\tfrac{p_2}{L}) & \\ \quad -\tfrac{\eta_1 L}{\eta_1+\eta_2}\mathrm{F}_2(\lambda_1-\tfrac{(p_1-p_2)}{L})[\lambda_1-\tfrac{(p_1-p_2)}{L}-\tfrac{1}{\eta_2}] & \text{where } \lambda_1-\tfrac{(p_1-p_2)}{L}\le\lambda_2\\ \tfrac{L\eta_2\lambda_2}{\eta_1+\eta_2}\mathrm{F}_1(\lambda_2+\tfrac{(p_1-p_2)}{L})-\tfrac{L}{\eta_1+\eta_2}\tfrac{p_2}{L}\mathrm{F}_1(\tfrac{p_1}{L})\mathrm{f}_2(\tfrac{p_2}{L})-(p_2+\tfrac{L}{\eta_1+\eta_2})\mu_2 & \text{where } \lambda_1-\tfrac{(p_1-p_2)}{L}>\lambda_2\end{cases}$$

Appendix 6.2 Reference pricing equilibria with identical drugs

For undercutting to be preferable to matching a shared price then:

$$\frac{\partial \pi_i(p_i,p_j)}{\partial p_i} < 0$$

$$\frac{\partial}{\partial p_i}\left[(p_i - c)\mu_i(p_i^c, p_j^c)\right] < 0$$

$$\frac{\partial}{\partial p_i}\left[(p_i - c)\mu_i(0,0)\right] < 0 \qquad \text{since } p_i = p_j$$

$$\mu_i(0,0) + (p_i - c)\frac{\partial \mu_i(0,0)}{\partial p_j^c}\frac{\partial p_j^c}{\partial p_i} < 0$$

and since undercutting is akin to increasing a competitors consumer price while leaving yours constant

$$\mu_i(0,0) - (p_i - c)\frac{\partial \mu_i(0,0)}{\partial p_j^c} < 0$$

$$\mu_i(0,0) < \frac{\partial \mu_i(0,0)}{\partial p_j^c}(p_i - c)$$

$$p_i > c + \frac{\mu_i(0,0)}{\frac{\partial \mu_i(0,0)}{\partial p_j^c}}$$

Since $\frac{\partial \mu_i(0,0)}{\partial p_j^c} > 0$ this maximum price is above cost.

For charging above the shared price to be optimal then

$$\frac{\partial \pi_i(p_i,p_j)}{\partial p_i} > 0$$

$$\frac{\partial}{\partial p_i}\left[(p_i - c)\mu_i(p_i^c, p_j^c)\right] > 0$$

$$\frac{\partial}{\partial p_i}\left[(p_i - c)\mu_i(0,0)\right] > 0 \qquad \text{since } p_i = p_j$$

$$\mu_i(0,0) + \frac{\partial \mu_i(0,0)}{\partial p_i^c}(p_i - c) > 0$$

$$\frac{\partial \mu_i(0,0)}{\partial p_i^c}(p_i - c) > -\mu_i(0,0)$$

$$p_i < c - \frac{\mu_i(0,0)}{\frac{\partial \mu_i(0,0)}{\partial p_i^c}}$$

Now since $\frac{\partial \mu_i(0,0)}{\partial p_i^c} < 0$ the maximum price is above cost.

Now since quantity is more responsive to an increase in a firm's own consumer price than a decrease in its competitors consumer price we can say:

$$\frac{\partial \mu_i(0,0)}{\partial p_j^c} < -\frac{\partial \mu_i(0,0)}{\partial p_i^c} \qquad \text{since both terms are positive}$$

$$\frac{\mu_i(0,0)}{\frac{\partial \mu_i(0,0)}{\partial p_j^c}} > -\frac{\mu_i(0,0)}{\frac{\partial \mu_i(0,0)}{\partial p_i^c}}$$

$$c + \frac{\mu_i(0,0)}{\frac{\partial \mu_i(0,0)}{\partial p_j^c}} > c - \frac{\mu_i(0,0)}{\frac{\partial \mu_i(0,0)}{\partial p_i^c}}$$

So that:

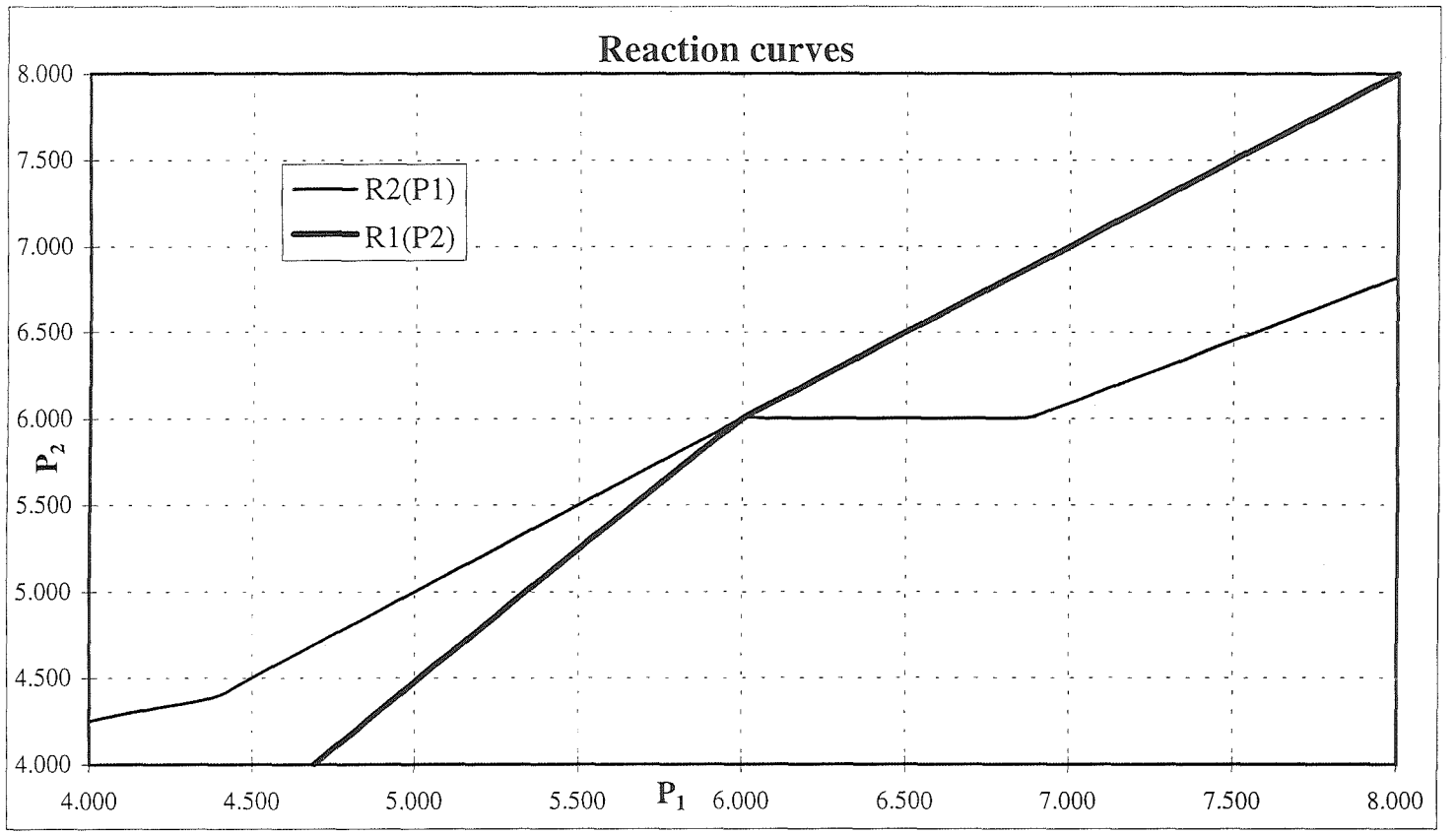
for a competitor's price below $c-\frac{\mu_i(0,0)}{\frac{\partial \mu_i(0,0)}{\partial p_i^c}}$ a firm will charge a premium since it prefers to do so rather than matching the competitors price. Since $p_j < c+\frac{\mu_i(0,0)}{\frac{\partial \mu_i(0,0)}{\partial p_j^c}}$ it also prefers matching the consumer price to undercutting.

for a competitors price above $c+\frac{\mu_i(0,0)}{\frac{\partial \mu_i(0,0)}{\partial p_j^c}}$ a firm will undercut since it prefers to do so rather than matching whatever price is charged by the competitor. Since $p_j > c-\frac{\mu_i(0,0)}{\frac{\partial \mu_i(0,0)}{\partial p_i^c}}$ it prefers matching the consumer price to charging a premium.

for a competitor's price above $c-\frac{\mu_i(0,0)}{\frac{\partial \mu_i(0,0)}{\partial p_i^c}}$ and below $c+\frac{\mu_i(0,0)}{\frac{\partial \mu_i(0,0)}{\partial p_j^c}}$ the producer prefers matching this price to deviating from it. Since both firms are identical and optimally choose the same price there is a range of equilibria in the case of identical drugs.

ɔpendix 6.3 Switch point for change of equilibrium type

chapter 6 the case of a difference in efficacy promoted a result where equilibrium consisted of a single int. The same case without a difference in efficacy resulted in a range of equilibria in the armaceutical market. The scenario at which the expected behaviour of the equilibrium changes from a ıge to a single point is of interest. Through analysis of the model the case where $\lambda_1 = 1, \lambda_2 = 0.825$ was ınd to be the point where the equilibrium type changes. The reaction curve, quantity and profits of ch firm are given on the following page.



	λ	η	c	P*	μ	π
DRUG 1	1.000	1.000	1.000	6.0000	0.4997	2.4983
DRUG 2	0.825	1.000	1.000	6.0000	0.3391	1.6956

ıpendix 6.4 The pricing system in New Zealand

Much of this appendix is reproduced from Woodfield, A and others (1997).

Pharmac negotiates over prices with manufacturers and the results of these negotiations appear in Pharmaceutical Schedule in the "manufacturer's price" or "subsidy" columns. These prices define the ɔsidy on offer for each drug and not necessarily the actual price at which trade occurs. These actual ces are not observed by Pharmac.

Manufacturers are paid by whomever receives their products, be they pharmacists or wholesalers ıarmac is a subsidising agency rather than a drug purchasing agency). Manufacturers may compete er the discounts they offer in order to gain the custom of pharmacists. Pharmacists keep any such ɔcounts without the knowledge of Pharmac who, presumably sets the fixed markups given below ɜuming these discounts are small or zero.

Pharmacists are reimbursed for purchasing pharmaceuticals at similar rates, irrespective of the ice they actually pay for the pharmaceuticals. The pharmacists receive a markup of 10% of the gotiated price if no wholesaler is used plus an 11.28% markup, in addition to fee for the containers ed to package drugs. All these charges can amount to quite a large sum. In addition to this fee the ɔril 1997 Pharmaceutical Schedule notes that an additional markup of up to 50% can be charged on the ısubsidised portion of the negotiated price. In all pharmacists appear to be in a very favourable ɔsition.

Depending on how or whether discounts are passed on to them patients may face prices at, above below the negotiated price. Without any empirical information no attempt was made to estimate the lationship between negotiated price and actual consumer price. By default the simplistic assumption at the consumer price equals the unsubsidised portion of the negotiated price throughout Chapters 6-10. nly in the sensitivity tests of Chapter 10 was this assumption relaxed.

ɔpendix 9.1 Definition of the marginal firm under screening

iis appendix assumes fixed costs of zero and a constant discount rate of δ.

: time t (where patents expire at time T) a firm with a marginal cost of c it receives the following profit accepts a price of p_t in return for charging at a consumer price of p_t^c.

$$
\begin{aligned}
&(p_t - c)\mu(p_t^c) + \delta(p_t - c)\mu(p_t^c) + \delta^2(p_t - c)\mu(p_t^c) + \ldots + \delta^{T-t-1}(p_t - c)\mu(p_t^c) \\
&= (p_t - c)\mu(p_t^c)(1 + \delta + \delta^2 + \ldots + \delta^{T-t-1}) \\
&= (p_t - c)\mu(p_t^c)((1 + \delta + \delta^2 + \ldots) - (\delta^{T-t} + \delta^{T-t+1} + \delta^{T-t+2} + \ldots)) \\
&= (p_t - c)\mu(p_t^c)(\frac{1}{1-\delta} - \frac{\delta^{T-t}}{1-\delta}) \\
&= \frac{1-\delta^{T-t}}{1-\delta}(p_t - c)\mu(p_t^c)
\end{aligned}
$$

the firm was to instead reject the offer and accept the next period's offer it receives

$$
\begin{aligned}
&(\overline{p} - c)\overline{\mu} + \delta(p_{t+1} - c)\mu(p_{t+1}^c) + \delta^2(p_{t+1} - c)\mu(p_{t+1}^c) + \ldots + \delta^{T-t-1}(p_{t+1} - c)\mu(p_{t+1}^c) \\
&= (\overline{p} - c)\overline{\mu} + \delta(p_{t+1} - c)\mu(p_{t+1}^c)(1 + \delta + \delta^2 + \ldots + \delta^{T-t-2}) \\
&= (\overline{p} - c)\overline{\mu} + \delta(p_{t+1} - c)\mu(p_{t+1}^c)((1 + \delta + \delta^2 + \ldots) - (\delta^{T-t-1} + \delta^{T-t} + \delta^{T-t+1} + \ldots)) \\
&= (\overline{p} - c)\overline{\mu} + \delta(p_{t+1} - c)\mu(p_{t+1}^c)(\frac{1}{1-\delta} - \frac{\delta^{T-t-1}}{1-\delta}) \\
&= (\overline{p} - c)\overline{\mu} + \delta\frac{1-\delta^{T-t-1}}{1-\delta}(p_{t+1} - c)\mu(p_{t+1}^c) \\
&= (\overline{p} - c)\overline{\mu} + \frac{\delta - \delta^{T-t}}{1-\delta}(p_{t+1} - c)\mu(p_{t+1}^c)
\end{aligned}
$$

Note that this term is not necessarily the profit accruing to a firm that rejects p_t but will equal the ejection profits for the marginal firm.[1] The simplest version of this model sees p_{t+1}^c constant over t. With $p_{t+1}^c = k$ firms face the profits:[2]

acceptance of today's offer: $\frac{1-\delta^{T-t}}{1-\delta}(p_t - c)\mu(k)$

wait until next period: $(\overline{p} - c)\overline{\mu} + \frac{\delta - \delta^{T-t}}{1-\delta}(p_{t+1} - c)\mu(k)$

[1] The precise definition of profits in the case of rejection is not required since where consumers join the scheme each period a marginal consumer is marginal over the choice of when to accept, not if.

[2] Any constant will do here but to retain consistency with earlier sections zero is used.

r the marginal firm these are equal.

$$(\tfrac{1-\delta^{T-t}}{1-\delta})(p_t - c^*)\mu(k) = (\overline{p} - c^*)\overline{\mu} + \tfrac{\delta-\delta^{T-t}}{1-\delta}(p_{t+1} - c^*)\mu(k)$$

$$1-\delta^{T-t})(p_t - c^*)\mu(k) = (1-\delta)(\overline{p} - c^*)\overline{\mu} + (\delta-\delta^{T-t})(p_{t+1} - c^*)\mu(k)$$

$$-(1-\delta)(\overline{p} - c^*)\overline{\mu} = (\delta-\delta^{T-t})(p_{t+1} - c^*)\mu(k) - (1-\delta^{T-t})(p_t - c^*)\mu(k)$$

$$(1-\delta)c^*\overline{\mu} - (1-\delta)\overline{p\mu} = \mu(k)[(\delta-\delta^{T-t})(p_{t+1} - c^*) - (1-\delta^{T-t})(p_t - c^*)]$$

$$= \mu(k)[(\delta-\delta^{T-t})p_{t+1} - (1-\delta^{T-t})p_t] - c^*\mu(k)[(\delta-\delta^{T-t}) - (1-\delta^{T-t})]$$

$$(1-\delta)c^*\overline{\mu} = \mu(k)[\delta p_{t+1} - \delta^{T-t}p_{t+1} - p_t + \delta^{T-t}p_t] + c^*(1-\delta)\mu(k)$$

$$-\delta)c^*\overline{\mu} - c^*(1-\delta)\mu(k) = \mu(k)[\delta p_{t+1} - \delta^{T-t}p_{t+1} - p_t + \delta^{T-t}p_t - \delta p_t + \delta p_t] + (1-\delta)\overline{p\mu}$$

$$(1-\delta)c^*(\overline{\mu} - \mu(k)) = \mu(k)[(-\delta^{T-t}p_{t+1} + \delta^{T-t}p_t + \delta p_{t+1} - \delta p_t) - (p_t - \delta p_t)] + (1-\delta)\overline{p\mu}$$

$$= \mu(k)[(\delta-\delta^{T-t})(p_{t+1} - p_t)] - \mu(k)(1-\delta)p_t + (1-\delta)\overline{p\mu}$$

$$= \mu(k)[(\delta-\delta^{T-t})(p_{t+1} - p_t)] - (1-\delta)[p_t\mu(k) - \overline{p\mu}]$$

$$c^* = \frac{\mu(k)}{\overline{\mu} - \mu(k)}\frac{\delta-\delta^{T-t}}{1-\delta}(p_{t+1} - p_t) - \frac{p_t\mu(k) - \overline{p\mu}}{\overline{\mu} - \mu(k)}$$

$$c^* = \frac{p_t\mu(k) - \overline{p\mu}}{\mu(k) - \overline{\mu}} - \frac{\mu(k)}{\mu(k) - \overline{\mu}}\frac{\delta-\delta^{T-t}}{1-\delta}(p_{t+1} - p_t)$$

ıpendix 9.2 Strategy of a firm under screening

time t (where patents expire at time T) a firm has a marginal cost of c it receives the following profit ccepts a price of p_t in return for charging at p_t^c.[3]

$$\frac{1-\delta^{T-t}}{1-\delta}(p_t-c)\mu(p_t^c)$$

he firm was to instead reject the offer and accept the next period's offer it receives

$$-c)\overline{\mu}+\frac{\delta-\delta^{T-t}}{1-\delta}(p_{t+1}-c)\mu(p_{t+1}^c)$$

Firm with cost c will accept subsidisation if and only if:

$$\frac{\delta^{T-t}}{-\delta}(p_t-c)\mu(p_t^c)>(\overline{p}-c)\overline{\mu}+\frac{\delta-\delta^{T-t}}{1-\delta}(p_{t+1}-c)\mu(p_{t+1}^c)$$

$$\frac{1-\delta^{T-t}}{1-\delta}(p_t-c)>(\overline{p}-c)\frac{\overline{\mu}}{\mu(p_t^c)}+\frac{\delta-\delta^{T-t}}{1-\delta}(p_{t+1}-c)\frac{\mu(p_{t+1}^c)}{\mu(p_t^c)}$$

$$(p_t-c)>(\overline{p}-c)\frac{1-\delta}{1-\delta^{T-t}}\frac{\overline{\mu}}{\mu(p_t^c)}+\frac{1-\delta}{1-\delta^{T-t}}\frac{\delta-\delta^{T-t}}{1-\delta}(p_{t+1}-c)\frac{\mu(p_{t+1}^c)}{\mu(p_t^c)}$$

$$p_t>c+(\overline{p}-c)\frac{1-\delta}{1-\delta^{T-t}}\frac{\overline{\mu}}{\mu(p_t^c)}+\frac{\delta-\delta^{T-t}}{1-\delta^{T-t}}(p_{t+1}-c)\frac{\mu(p_{t+1}^c)}{\mu(p_t^c)}$$

Assuming zero fixed costs.

ppendix 9.3 Incorporation of an unsubsidised firm's reaction function.

anges in the consumer price of competing drugs affect the function $\mu(p^p)$. Firm 1 is in the process of gotiating subsidisation and faces an unsubsidised competitor firm 2. Firm 1 has a quantity function $_1^p(t)) = \mu_1\left(p_1^p(t), p_2\right)$ so that subsidisation defines the price it charges once subsidised but not the ce of firm 2. This new quantity function can be inserted into the profit function under a signalling uilibrium.

$$\pi(c) = \max_t \left\{(\bar{p}-c)\bar{\mu}\left[\tfrac{1}{r}-\tfrac{1}{r}e^{-rt}\right]+(p(t)-c)\mu_1\left(p_1^p(t), p_2\right)\left[\tfrac{1}{r}e^{-rt}-\tfrac{1}{r}e^{-rT}\right]\right\}$$

ow to find the equilibrium the first order condition for the interior of this function is analysed

$$0 = (\bar{p}-c)\bar{\mu}e^{-rt} - (p_1(t)-c)\mu_1\left(p_1^p(t), p_2\right)e^{-rt} + \frac{dp}{dt}\mu_1\left(p_1^p(t), p_2\right)\left[\tfrac{1}{r}e^{-rt}-\tfrac{1}{r}e^{-rT}\right]$$
$$+\frac{d\mu_1}{dp_1^p}\frac{dp_1^p}{dp_1}(p_1(t)-c)\left[\tfrac{1}{r}e^{-rt}-\tfrac{1}{r}e^{-rT}\right]$$

d the reaction function of firm 2 ($R_2(p_1^p)$) inserted in place of p_2:

$$= (\bar{p}-c)\bar{\mu}e^{-rt} - (p_1(t)-c)\mu_1\left(p_1^p(t), R_2(p_1^p)\right)e^{-rt} + \frac{dp}{dt}\mu_1\left(p_1^p(t), R_2(p_1^p)\right)\left[\tfrac{1}{r}e^{-rt}-\tfrac{1}{r}e^{-rT}\right]$$
$$+\frac{d\mu_1}{dp_1^p}\frac{dp_1^p}{dp_1}(p_1(t)-c)\left[\tfrac{1}{r}e^{-rt}-\tfrac{1}{r}e^{-rT}\right]$$

ice simplified with $c = c(t)$ and solved this first-order condition will give a signalling equilibrium that corporates the reaction of a firm's competitors to subsidisation.

Appendix 10.1 Comparison of subsidisation frameworks.

The following tables contain the full results of the comparisons referred to in Chapter 10. The legend below gives the names and quantities for each figure displayed on the following tables.

name	explanation
pprice	equilibrium producer price
cprice	equilibrium consumer price
quantity	quantity over full period to generic entry
profits	profits over full period to generic entry
subsidies	subsidies required over full period to generic entry
cs	consumer surplus over full period to generic entry
ts	total surplus over full period to generic entry
pbar	for JZ scheme only: price charged by entrant pre-subsidisation
tcrit	for JZ scheme only: time elapsed when subsidisation accepted

Identically Distributed Drugs

lambda	1.0000	1.0000	eta	1.0000	1.0000	cost	0.0000	0.0000
REFERENCE PRICING			**JZ VARIANT**			**NO SUBSIDISATION OF SECOND DRUG**		
pprice	2.5532	2.5532	pprice	2.3108	2.5532	pprice	2.3935	2.5532
cprice	0.0000	0.0000	cprice	0.0000	0.0000	cprice	2.3935	0.0000
quantity	1.9459	1.9459	quantity	1.9459	1.9459	quantity	0.9028	2.6150
profits	4.9685	4.9685	profits	4.4966	4.9683	profits	2.1608	6.6769
subsidies	9.9369		subsidies	9.4649		subsidies	6.6769	
cs	12.7751		cs	12.7751		cs	9.4296	
ts	12.7751		ts	12.7751		ts	11.5904	
			pbar	3.4215				
			tcrit	0.0000				
lambda	1.0000	1.0000	eta	1.0000	1.0000	cost	1.0000	0.0000
REFERENCE PRICING			**JZ VARIANT**			**NO SUBSIDISATION OF SECOND DRUG**		
pprice	2.5532	2.5532	pprice	2.3673	2.5532	pprice	2.9459	2.5532
cprice	0.0000	0.0000	cprice	0.0000	0.0000	cprice	2.9459	0.0000
quantity	1.9459	1.9459	quantity	1.8710	1.9890	quantity	0.6995	2.7034
profits	3.0226	4.9685	profits	2.5878	5.0785	profits	1.3612	6.9027
subsidies	9.9369		subsidies	9.4417		subsidies	6.9027	
cs	12.7751		cs	12.5593		cs	8.9875	
ts	10.8292		ts	10.6883		ts	10.3487	
			pbar	3.4353				
			tcrit	0.2405				
lambda	1.0000	1.0000	eta	1.0000	1.0000	cost	2.0000	0.0000
REFERENCE PRICING			**JZ VARIANT**			**NO SUBSIDISATION OF SECOND DRUG**		
pprice	2.5532	2.5532	pprice	2.3888	2.5532	pprice	3.4773	2.5532
cprice	0.0000	0.0000	cprice	0.0000	0.0000	cprice	3.4773	0.0000
quantity	1.9459	1.9459	quantity	1.7905	2.0349	quantity	0.5121	2.7677
profits	1.0767	4.9685	profits	0.7565	5.1956	profits	0.7565	7.0669
subsidies	9.9369		subsidies	9.3402		subsidies	7.0669	
cs	12.7751		cs	12.3298		cs	8.6658	
ts	8.8833		ts	8.7488		ts	9.4223	
			pbar	3.4773				
			tcrit	0.5000				

Identically Distributed Drugs

lambda	1.0000	1.0000	eta	1.0000	1.0000	cost	0.0000	1.0000
REFERENCE PRICING			**JZ VARIANT**			**NO SUBSIDISATION OF SECOND DRUG**		
pprice	2.6002	2.6002	pprice	2.3108	2.6002	pprice	2.3935	2.6002
cprice	0.0000	0.0000	cprice		0.0000	cprice	2.3935	0.0000
quantity	1.9459	1.9459	quantity	1.9459	1.9459	quantity	0.9028	2.6150
profits	5.0597	3.1138	profits	4.4966	3.1138	profits	2.1608	4.1845
subsidies	10.1194		subsidies	9.5563		subsidies	6.7995	
cs	12.7751		cs	12.7751		cs	9.4296	
ts	10.8292		ts	10.8292		ts	8.9754	
			pbar	3.4215				
			tcrit	0.0000				
lambda	1.0000	1.0000	eta	1.0000	1.0000	cost	1.0000	1.0000
REFERENCE PRICING			**JZ VARIANT**			**NO SUBSIDISATION OF SECOND DRUG**		
pprice	2.6002	2.6002	pprice	2.3673	2.6002	pprice	2.9459	2.6002
cprice	0.0000	0.0000	cprice	0.0000	0.0000	cprice	2.9459	0.0000
quantity	1.9459	1.9459	quantity	1.8710	1.9890	quantity	0.6995	2.7034
profits	3.1138	3.1138	profits	2.5878	3.1829	profits	1.3612	4.3260
subsidies	10.1194		subsidies	9.5352		subsidies	7.0294	
cs	12.7751		cs	12.5593		cs	8.9875	
ts	8.8833		ts	8.6993		ts	7.6453	
	3.1138	3.1138	pbar	3.4353				
			tcrit	0.2405				
lambda	1.0000	1.0000	eta	1.0000	1.0000	cost	2.0000	1.0000
REFERENCE PRICING			**JZ VARIANT**			**NO SUBSIDISATION OF SECOND DRUG**		
pprice	2.6002	2.6002	pprice	2.3888	2.6002	pprice	3.4773	2.6002
cprice	0.0000	0.0000	cprice	0.0000	0.0000	cprice	3.4773	0.0000
quantity	1.9459	1.9459	quantity	1.7905	2.0349	quantity	0.5121	2.7677
profits	1.1679	3.1138	profits	0.7565	3.2563	profits	0.7565	4.4289
subsidies	10.1194		subsidies	9.4358		subsidies	7.1967	
cs	12.7751		cs	12.3298		cs	8.6658	
ts	6.9374		ts	6.7138		ts	6.6546	
			pbar	3.4773				
			tcrit	0.5000				

Identically Distributed Drugs

lambda	1.0000	1.0000	eta	1.0000	1.0000	cost	0.0000	2.0000
REFERENCE PRICING			**JZ VARIANT**			**NO SUBSIDISATION OF SECOND DRUG**		
pprice	2.6182	2.6182	pprice	2.3108	2.6182	pprice	2.3935	2.6182
cprice	0.0000	0.0000	cprice	0.0000	0.0000	cprice	2.3935	0.0000
quantity	1.9459	1.9459	quantity	1.9459	1.9459	quantity	0.9028	2.6150
profits	5.0946	1.2029	profits	4.4966	1.2029	profits	2.1608	1.6166
subsidies	10.1893		subsidies	9.5912		subsidies	6.8465	
cs	12.7751		cs	12.7751		cs	9.4296	
ts	8.8833		ts	8.8833		ts	6.3605	
			pbar	3.4215				
			tcrit	0.0000				
lambda	1.0000	1.0000	eta	1.0000	1.0000	cost	1.0000	2.0000
REFERENCE PRICING			**JZ VARIANT**			**NO SUBSIDISATION OF SECOND DRUG**		
pprice	2.6182	2.6182	pprice	2.3673	2.6182	pprice	2.9459	2.6182
cprice	0.0000	0.0000	cprice	0.0000	0.0000	cprice	2.9459	0.0000
quantity	1.9459	1.9459	quantity	1.8710	1.9890	quantity	0.6995	2.7034
profits	3.1488	1.2029	profits	2.5878	1.2296	profits	1.3612	1.6712
subsidies	10.1893		subsidies	9.5709		subsidies	7.0780	
cs	12.7751		cs	12.5593		cs	8.9875	
ts	6.9375		ts	6.7102		ts	4.9420	
			pbar	3.4353				
			tcrit	0.2405				
lambda	1.0000	1.0000	eta	1.0000	1.0000	cost	2.0000	2.0000
REFERENCE PRICING			**JZ VARIANT**			**NO SUBSIDISATION OF SECOND DRUG**		
pprice	2.6182	2.6182	pprice	2.3888	2.6182	pprice	3.4773	2.6182
cprice	0.0000	0.0000	cprice	0.0000	0.0000	cprice	3.4773	0.0000
quantity	1.9459	1.9459	quantity	1.7905	2.0349	quantity	0.5121	2.7677
profits	1.2029	1.2029	profits	0.7565	1.2579	profits	0.7565	1.7109
subsidies	10.1893		subsidies	9.4724		subsidies	7.2464	
cs	12.7751		cs	12.3298		cs	8.6658	
ts	4.9915		ts	4.6789		ts	3.8869	
			pbar	3.4773				
			tcrit	0.5000				

Balanced asymmetry (λ=0.85, η=1.10 previously subsidised)

lambda	0.9000	0.8500	eta	1.0000	1.1000	cost	0.0000	0.0000
REFERENCE PRICING			**JZ VARIANT**			**NO SUBSIDISATION OF SECOND DRUG**		
pprice	2.3381	2.3381	pprice	2.2129	2.3381	pprice	2.1385	2.3381
cprice	0.0000	0.0000	cprice	0.0000	0.0000	cprice	2.1385	0.0000
quantity	1.8254	1.9620	quantity	1.8254	1.9620	quantity	0.8423	2.5593
profits	4.2680	4.5875	profits	4.0393	4.5875	profits	1.8013	5.9840
subsidies	8.8554		subsidies	8.6268		subsidies	5.9840	
cs	10.6732		cs	10.6732		cs	7.7238	
ts	10.6732		ts	10.6732		ts	9.5251	
			pbar	3.1718				
			tcrit	0.0000				
lambda	0.9000	0.8500	eta	1.0000	1.1000	cost	1.0000	0.0000
REFERENCE PRICING			**JZ VARIANT**			**NO SUBSIDISATION OF SECOND DRUG**		
pprice	2.3381	2.3381	pprice	2.2711	2.3381	pprice	2.6945	2.3381
cprice	0.0000	0.0000	cprice	0.0000	0.0000	cprice	2.6945	0.0000
quantity	1.8254	1.9620	quantity	1.7528	2.0006	quantity	0.6298	2.6416
profits	2.4426	4.5875	profits	2.2499	4.6776	profits	1.0671	6.1765
subsidies	8.8554		subsidies	8.6045		subsidies	6.1765	
cs	10.6732		cs	10.4799		cs	7.2920	
ts	8.8478		ts	8.7271		ts	8.3591	
			pbar	3.1855				
			tcrit	0.2405				
lambda	0.9000	0.8500	eta	1.0000	1.1000	cost	2.0000	0.0000
REFERENCE PRICING			**JZ VARIANT**			**NO SUBSIDISATION OF SECOND DRUG**		
pprice	2.3381	2.3381	pprice	2.2934	2.3381	pprice	3.2277	2.3381
cprice	0.0000	0.0000	cprice	0.0000	0.0000	cprice	3.2277	0.0000
quantity	1.8254	1.9620	quantity	1.6748	2.0416	quantity	0.4362	2.6961
profits	0.6172	4.5875	profits	0.5355	4.7734	profits	0.5355	6.3037
subsidies	8.8554		subsidies	8.5060		subsidies	6.3037	
cs	10.6732		cs	10.2743		cs	6.9922	
ts	7.0225		ts	6.9246		ts	7.5276	
			pbar	3.2277				
			tcrit	0.5000				

Balanced asymmetry (λ=0.85, η=1.10 previously subsidised)

lambda	0.9000	0.8500	eta	1.0000	1.1000	cost	0.0000	1.0000
REFERENCE PRICING			**JZ VARIANT**			**NO SUBSIDISATION OF SECOND DRUG**		
pprice	2.3883	2.3883	pprice	2.2129	2.3883	pprice	2.1385	2.3883
cprice	0.0000	0.0000	cprice	0.0000	0.0000	cprice	2.1385	0.0000
quantity	1.8254	1.9620	quantity	1.8254	1.9620	quantity	0.8423	2.5593
profits	4.3595	2.7238	profits	4.0393	2.7238	profits	1.8013	3.5530
subsidies	9.0453		subsidies	8.7252		subsidies	6.1123	
cs	10.6732		cs	10.6732		cs	7.7238	
ts	8.7112		ts	8.7112		ts	6.9658	
			pbar	3.1718				
			tcrit	0.0000				

lambda	0.9000	0.8500	eta	1.0000	1.1000	cost	1.0000	1.0000
REFERENCE PRICING			**JZ VARIANT**			**NO SUBSIDISATION OF SECOND DRUG**		
pprice	2.3883	2.3883	pprice	2.2711	2.3883	pprice	2.6945	2.3883
cprice	0.0000	0.0000	cprice	0.0000	0.0000	cprice	2.6945	0.0000
quantity	1.8254	1.9620	quantity	1.7528	2.0006	quantity	0.6298	2.6416
profits	2.5341	2.7238	profits	2.2499	2.7774	profits	1.0671	3.6673
subsidies	9.0453		subsidies	8.7048		subsidies	6.3089	
cs	10.6732		cs	10.4799		cs	7.2920	
ts	6.8858		ts	6.7265		ts	5.7175	
			pbar	3.1855				
			tcrit	0.2405				

lambda	0.9000	0.8500	eta	1.0000	1.1000	cost	2.0000	1.0000
REFERENCE PRICING			**JZ VARIANT**			**NO SUBSIDISATION OF SECOND DRUG**		
pprice	2.3883	2.3883	pprice	2.2934	2.3883	pprice	3.2277	2.3883
cprice	0.0000	0.0000	cprice	0.0000	0.0000	cprice	3.2277	0.0000
quantity	1.8254	1.9620	quantity	1.6748	2.0416	quantity	0.4362	2.6961
profits	0.7088	2.7238	profits	0.5355	2.8342	profits	0.5355	3.7429
subsidies	9.0453		subsidies	8.6084		subsidies	6.4389	
cs	10.6732		cs	10.2743		cs	6.9922	
ts	5.0604		ts	4.8831		ts	4.8316	
			pbar	3.2277				
			tcrit	0.5000				

Balanced asymmetry (λ=0.85, η=1.10 previously subsidised)

lambda	0.9000	0.8500	eta	1.0000	1.1000	cost	0.0000	2.0000
REFERENCE PRICING			**JZ VARIANT**			**NO SUBSIDISATION OF SECOND DRUG**		
pprice	2.4075	2.4075	pprice	2.2129	2.4075	pprice	2.1385	2.4075
cprice	0.0000	0.0000	cprice	0.0000	0.0000	cprice	2.1385	0.0000
quantity	1.8254	1.9620	quantity	1.8254	1.9620	quantity	0.8423	2.5593
profits	4.3938	0.7987	profits	4.0393	0.7995	profits	1.8013	1.0418
subsidies	9.1165		subsidies	8.7629		subsidies	6.1604	
cs	10.6732		cs	10.6732		cs	7.7238	
ts	6.7492		ts	6.7492		ts	4.4065	
			pbar	3.1718				
			tcrit	0.0000				

lambda	0.9000	0.8500	eta	1.0000	1.1000	cost	1.0000	2.0000
REFERENCE PRICING			**JZ VARIANT**			**NO SUBSIDISATION OF SECOND DRUG**		
pprice	2.4075	2.4075	pprice	2.2711	2.4075	pprice	2.6945	2.4075
cprice	0.0000	0.0000	cprice	0.0000	0.0000	cprice	2.6945	0.0000
quantity	1.8254	1.9620	quantity	1.7528	2.0006	quantity	0.6298	2.6416
profits	2.5684	0.7987	profits	2.2499	0.8153	profits	1.0671	1.0753
subsidies	9.1165		subsidies	8.7433		subsidies	6.3586	
cs	10.6732		cs	10.4799		cs	7.2920	
ts	4.9238		ts	4.7259		ts	3.0759	
			pbar	3.1855				
			tcrit	0.2405				

lambda	0.9000	0.8500	eta	1.0000	1.1000	cost	2.0000	2.0000
REFERENCE PRICING			**JZ VARIANT**			**NO SUBSIDISATION OF SECOND DRUG**		
pprice	2.4075	2.4075	pprice	2.2934	2.4075	pprice	3.2277	2.4075
cprice	0.0000	0.0000	cprice	0.0000	0.0000	cprice	3.2277	0.0000
quantity	1.8254	1.9620	quantity	1.6748	2.0416	quantity	0.4362	2.6961
profits	0.7430	0.7987	profits	0.5355	0.8319	profits	0.5355	1.0975
subsidies	9.1165		subsidies	8.6477		subsidies	6.4896	
cs	10.6732		cs	10.2743		cs	6.9922	
ts	3.0984		ts	2.8415		ts	2.1355	
			pbar	3.2277				
			tcrit	0.5000				

Balanced asymmetry (λ=0.90, η=1.00 previously subsidised)

lambda	1.0000	0.9000	eta	1.1000	1.0000	cost	0.0000	0.0000
REFERENCE PRICING			**JZ VARIANT**			**NO SUBSIDISATION OF SECOND DRUG**		
pprice	2.3994	2.3994	pprice	2.1925	2.3994	pprice	2.0765	2.3994
cprice	0.0000	0.0000	cprice	0.0000	0.0000	cprice	2.0765	0.0000
quantity	1.9620	1.8254	quantity	1.9620	1.8254	quantity	0.9317	2.4371
profits	4.7076	4.3797	profits	4.3017	4.3797	profits	1.9346	5.8475
subsidies	9.0873		subsidies	8.6814		subsidies	5.8475	
cs	10.6732		cs	10.6732		cs	7.8528	
ts	10.6732		ts	10.6732		ts	9.7875	
			pbar	3.0667				
			tcrit	0.0000				
lambda	1.0000	0.9000	eta	1.1000	1.0000	cost	1.0000	0.0000
REFERENCE PRICING			**JZ VARIANT**			**NO SUBSIDISATION OF SECOND DRUG**		
pprice	2.3994	2.3994	pprice	2.2504	2.3994	pprice	2.6066	2.3994
cprice	0.0000	0.0000	cprice	0.0000	0.0000	cprice	2.6066	0.0000
quantity	1.9620	1.8254	quantity	1.8845	1.8659	quantity	0.6979	2.5301
profits	2.7456	4.3797	profits	2.3780	4.4770	profits	1.1212	6.0705
subsidies	9.0873		subsidies	8.6592		subsidies	6.0705	
cs	10.6732		cs	10.4885		cs	7.4423	
ts	8.7112		ts	8.6392		ts	8.5635	
			pbar	3.0800				
			tcrit	0.2405				
lambda	1.0000	0.9000	eta	1.1000	1.0000	cost	2.0000	0.0000
REFERENCE PRICING			**JZ VARIANT**			**NO SUBSIDISATION OF SECOND DRUG**		
pprice	2.3994	2.3994	pprice	2.2725	2.3994	pprice	3.1209	2.3994
cprice	0.0000	0.0000	cprice	0.0000	0.0000	cprice	3.1209	0.0000
quantity	1.9620	1.8254	quantity	1.8011	1.9091	quantity	0.4770	2.5977
profits	0.7835	4.3797	profits	0.5346	4.5853	profits	0.5346	6.2329
subsidies	9.0873		subsidies	8.5560		subsidies	6.2329	
cs	10.6732		cs	10.2920		cs	7.1551	
ts	6.7492		ts	6.6898		ts	7.6897	
			pbar	3.1209				
			tcrit	0.5000				

Balanced asymmetry (λ=0.90, η=1.00 previously subsidised)

lambda	1.0000	0.9000	eta	1.1000	1.0000	cost	0.0000	1.0000
REFERENCE	**PRICING**		**JZ VARIANT**			**NO SUBSIDISATION OF SECOND DRUG**		
pprice	2.4487	2.4487	pprice	2.1925	2.4487	pprice	2.0765	2.4487
cprice	0.0000	0.0000	cprice	0.0000	0.0000	cprice	2.0765	0.0000
quantity	1.9620	1.8254	quantity	1.9620	1.8254	quantity	0.9317	2.4371
profits	4.8044	2.6444	profits	4.3017	2.6444	profits	1.9346	3.5307
subsidies	9.2742		subsidies	8.7715		subsidies	5.9678	
cs	10.6732		cs	10.6732		cs	7.8528	
ts	8.8478		ts	8.8478		ts	7.3504	
			pbar	3.0667				
			tcrit	0.0000				

lambda	1.0000	0.9000	eta	1.1000	1.0000	cost	1.0000	1.0000
REFERENCE	**PRICING**		**JZ VARIANT**			**NO SUBSIDISATION OF SECOND DRUG**		
pprice	2.4487	2.4487	pprice	2.2504	2.4487	pprice	2.6066	2.4487
cprice	0.0000	0.0000	cprice	0.0000	0.0000	cprice	2.6066	0.0000
quantity	1.9620	1.8254	quantity	1.8845	1.8659	quantity	0.6979	2.5301
profits	2.8424	2.6444	profits	2.3780	2.7032	profits	1.1212	3.6653
subsidies	9.2742		subsidies	8.7513		subsidies	6.1954	
cs	10.6732		cs	10.4885		cs	7.4423	
ts	6.8858		ts	6.7380		ts	6.0334	
			pbar	3.0800				
			tcrit	0.2405				

lambda	1.0000	0.9000	eta	1.1000	1.0000	cost	2.0000	1.0000
REFERENCE	**PRICING**		**JZ VARIANT**			**NO SUBSIDISATION OF SECOND DRUG**		
pprice	2.4487	2.4487	pprice	2.2725	2.4487	pprice	3.1209	2.4487
cprice	0.0000	0.0000	cprice	0.0000	0.0000	cprice	3.1209	0.0000
quantity	1.9620	1.8254	quantity	1.8011	1.9091	quantity	0.4770	2.5977
profits	0.8804	2.6444	profits	0.5346	2.7657	profits	0.5346	3.7633
subsidies	9.2742		subsidies	8.6502		subsidies	6.3611	
cs	10.6732		cs	10.2920		cs	7.1551	
ts	4.9238		ts	4.7807		ts	5.0920	
			pbar	3.1209				
			tcrit	0.5000				

Balanced asymmetry (λ=0.90, η=1.00 previously subsidised)

lambda	1.0000	0.9000	eta	1.1000	1.0000	cost	0.0000	2.0000
REFERENCE	**PRICING**		**JZ VARIANT**			**NO SUBSIDISATION OF SECOND DRUG**		
pprice	2.4676	2.4676	pprice	2.1925	2.4676	pprice	2.0765	2.4676
cprice	0.0000	0.0000	cprice	0.0000	0.0000	cprice	2.0765	0.0000
quantity	1.9620	1.8254	quantity	1.9620	1.8254	quantity	0.9317	2.4371
profits	4.8415	0.8536	profits	4.3017	0.8536	profits	1.9346	1.1396
subsidies	9.3458		subsidies	8.8060		subsidies	6.0139	
cs	10.6732		cs	10.6732		cs	7.8528	
ts	7.0224		ts	7.0224		ts	4.9132	
			pbar	3.0667				
			tcrit	0.0000				
lambda	1.0000	0.9000	eta	1.1000	1.0000	cost	1.0000	2.0000
REFERENCE	**PRICING**		**JZ VARIANT**			**NO SUBSIDISATION OF SECOND DRUG**		
pprice	2.4676	2.4676	pprice	2.2504	2.4676	pprice	2.6066	2.4676
cprice	0.0000	0.0000	cprice	0.0000	0.0000	cprice	2.6066	0.0000
quantity	1.9620	1.8254	quantity	1.8845	1.8659	quantity	0.6979	2.5301
profits	2.8795	0.8536	profits	2.3780	0.8725	profits	1.1212	1.1831
subsidies	9.3458		subsidies	8.7865		subsidies	6.2432	
cs	10.6732		cs	10.4885		cs	7.4423	
ts	5.0604		ts	4.8721		ts	3.5034	
			pbar	3.0800				
			tcrit	0.2405				
lambda	1.0000	0.9000	eta	1.1000	1.0000	cost	2.0000	2.0000
REFERENCE	**PRICING**		**JZ VARIANT**			**NO SUBSIDISATION OF SECOND DRUG**		
pprice	2.4676	2.4676	pprice	2.2725	2.4676	pprice	3.1209	2.4676
cprice	0.0000	0.0000	cprice	0.0000	0.0000	cprice	3.1209	0.0000
quantity	1.9620	1.8254	quantity	1.8011	1.9091	quantity	0.4770	2.5977
profits	0.9175	0.8536	profits	0.5346	0.8927	profits	0.5346	1.2147
subsidies	9.3458		subsidies	8.6863		subsidies	6.4102	
cs	10.6732		cs	10.2920		cs	7.1551	
ts	3.0984		ts	2.8717		ts	2.4943	
			pbar	3.1209				
			tcrit	0.5000				

Difference in efficacy (λ=1.00, η=1.00 previously subsidised)

lambda	0.5000	1.0000	eta	1.0000	1.0000	cost	0.0000	0.0000
REFERENCE PRICING			**JZ VARIANT**			**NO SUBSIDISATION OF SECOND DRUG**		
pprice	2.5532	2.5532	pprice	1.9288	2.5532	pprice	1.2369	2.5532
cprice	0.0000	0.0000	cprice	0.0000	0.0000	cprice	1.2369	0.0000
quantity	1.4226	2.2943	quantity	1.4226	2.2943	quantity	0.6970	2.6257
profits	3.6322	5.8581	profits	2.7438	5.8578	profits	0.8621	6.7041
subsidies	9.4903		subsidies	8.6017		subsidies	6.7041	
cs	9.3355		cs	9.3355		cs	8.5445	
ts	9.3355		ts	9.3355		ts	9.4066	
			pbar	2.1966				
			tcrit	0.0000				
lambda	0.5000	1.0000	eta	1.0000	1.0000	cost	1.0000	0.0000
REFERENCE PRICING			**JZ VARIANT**			**NO SUBSIDISATION OF SECOND DRUG**		
pprice	2.5532	2.5532	pprice	1.9976	2.5532	pprice	1.7472	2.5532
cprice	0.0000	0.0000	cprice	0.0000	0.0000	cprice	1.7472	0.0000
quantity	1.4226	2.2943	quantity	1.3558	2.3212	quantity	0.4126	2.7278
profits	2.2097	5.8581	profits	1.3543	5.9266	profits	0.3083	6.9651
subsidies	9.4903		subsidies	8.6182		subsidies	6.9651	
cs	9.3355		cs	9.2805		cs	8.3730	
ts	7.9130		ts	7.9247		ts	8.6812	
			pbar	2.2097				
			tcrit	0.2405				
lambda	0.5000	1.0000	eta	1.0000	1.0000	cost	2.0000	0.0000
REFERENCE PRICING			**JZ VARIANT**			**NO SUBSIDISATION OF SECOND DRUG**		
pprice	2.5532	2.5532	pprice	2.0240	2.5532	pprice	2.2499	2.5532
cprice	0.0000	0.0000	cprice	0.0000	0.0000	cprice	2.2499	0.0000
quantity	1.4226	2.2943	quantity	1.2832	2.3502	quantity	0.1366	2.8104
profits	0.7871	5.8581	profits	0.0341 4	6.00062	profits	0.0341	7.1759
subsidies	9.4903		subsidies	8.5679		subsidies	7.1759	
cs	9.3355		cs	9.2222		cs	8.2893	
ts	6.4904		ts	6.6558		ts	8.3234	
			pbar	2.2499				
			tcrit	0.5000				

Difference in efficacy (λ=1.00, η=1.00 previously subsidised)

lambda	0.5000	1.0000	eta	1.0000	1.0000	cost	0.0000	1.0000
REFERENCE PRICING			**JZ VARIANT**			**NO SUBSIDISATION OF SECOND DRUG**		
pprice	2.6002	2.6002	pprice	1.9288	2.6002	pprice	1.2369	2.6002
cprice	0.0000	0.0000	cprice	0.0000	0.0000	cprice	1.2369	0.0000
quantity	1.4226	2.2943	quantity	1.4226	2.2943	quantity	0.6970	2.6257
profits	3.6989	3.6713	profits	2.7438	3.6713	profits	0.8621	4.2016
subsidies	9.6645		subsidies	8.7095		subsidies	6.8272	
cs	9.3355		cs	9.3355		cs	8.5445	
ts	7.0413		ts	7.0413		ts	6.7810	
			pbar	2.1966				
			tcrit	0.0000				
lambda	0.5000	1.0000	eta	1.0000	1.0000	cost	1.0000	1.0000
REFERENCE PRICING			**JZ VARIANT**			**NO SUBSIDISATION OF SECOND DRUG**		
pprice	2.6002	2.6002	pprice	1.9976	2.6002	pprice	1.7472	2.6002
cprice	0.0000	0.0000	cprice	0.0000	0.0000	cprice	1.7472	0.0000
quantity	1.4226	2.2943	quantity	1.3558	2.3212	quantity	0.4126	2.7278
profits	2.2764	3.6713	profits	1.3543	3.7144	profits	0.3083	4.3651
subsidies	9.6645		subsidies	8.7273		subsidies	7.0929	
cs	9.3355		cs	9.2805		cs	8.3730	
ts	5.6187		ts	5.6035		ts	5.9534	
			pbar	2.2097				
			tcrit	0.2405				
lambda	0.5000	1.0000	eta	1.0000	1.0000	cost	2.0000	1.0000
REFERENCE PRICING			**JZ VARIANT**			**NO SUBSIDISATION OF SECOND DRUG**		
pprice	2.6002	2.6002	pprice	2.0240	2.6002	pprice	2.2499	2.6002
cprice	0.0000	0.0000	cprice	0.0000	0.0000	cprice	2.2499	0.0000
quantity	1.4226	2.2943	quantity	1.2832	2.3502	quantity	0.1366	2.8104
profits	0.8538	3.6713	profits	0.0341 4	3.76082	profits	0.0341	4.4973
subsidies	9.6645		subsidies	8.6783		subsidies	7.3077	
cs	9.3355		cs	9.2222		cs	8.2893	
ts	4.1961		ts	4.3055		ts	5.5130	
			pbar	2.2499				
			tcrit	0.5000				

Difference in efficacy (λ=1.00, η=1.00 previously subsidised)

lambda	0.5000	1.0000	eta	1.0000	1.0000	cost	0.0000	2.0000
REFERENCE PRICING			**JZ VARIANT**			**NO SUBSIDISATION OF SECOND DRUG**		
pprice	2.6182	2.6182	pprice	1.9288	2.6182	pprice	1.2369	2.6182
cprice	0.0000	0.0000	cprice	0.0000	0.0000	cprice	1.2369	0.0000
quantity	1.4226	2.2943	quantity	1.4226	2.2943	quantity	0.6970	2.6257
profits	3.7245	1.4183	profits	2.7438	1.4183	profits	0.8621	1.6232
subsidies	9.7313		subsidies	8.7507		subsidies	6.8744	
cs	9.3355		cs	9.3355		cs	8.5445	
ts	4.7470		ts	4.7470		ts	4.1554	
			pbar	2.1966				
			tcrit	0.0000				
lambda	0.5000	1.0000	eta	1.0000	1.0000	cost	1.0000	2.0000
REFERENCE PRICING			**JZ VARIANT**			**NO SUBSIDISATION OF SECOND DRUG**		
pprice	2.6182	2.6182	pprice	1.9976	2.6182	pprice	1.7472	2.6182
cprice	0.0000	0.0000	cprice	0.0000	0.0000	cprice	1.7472	0.0000
quantity	1.4226	2.2943	quantity	1.3558	2.3212	quantity	0.4126	2.7278
profits	2.3019	1.4183	profits	1.3543	1.4349	profits	0.3083	1.6864
subsidies	9.7313		subsidies	8.7690		subsidies	7.1419	
cs	9.3355		cs	9.2805		cs	8.3730	
ts	3.3244		ts	3.2822		ts	3.2256	
			pbar	2.2097				
			tcrit	0.2405				
lambda	0.5000	1.0000	eta	1.0000	1.0000	cost	2.0000	2.0000
REFERENCE PRICING			**JZ VARIANT**			**NO SUBSIDISATION OF SECOND DRUG**		
pprice	2.6182	2.6182	pprice	2.0240	2.6182	pprice	2.2499	2.6182
cprice	0.0000	0.0000	cprice	0.0000	0.0000	cprice	2.2499	0.0000
quantity	1.4226	2.2943	quantity	1.2832	2.3502	quantity	0.1366	2.8104
profits	0.8794	1.4183	profits	0.0341 4	1.45282	profits	0.0341	1.7373
subsidies	9.7313		subsidies	8.7205		subsidies	7.3582	
cs	9.3355		cs	9.2222		cs	8.2893	
ts	1.9019		ts	1.9553		ts	2.7026	
			pbar	2.2499				
			tcrit	0.5000				

Difference in efficacy (λ=0.50, η=1.00 previously subsidised)

lambda	1.0000	0.5000	eta	1.0000	1.0000	cost	0.0000	0.0000
REFERENCE PRICING			**JZ VARIANT**			**NO SUBSIDISATION OF SECOND DRUG**		
pprice	1.9389	1.9389	pprice	2.2474	1.9389	pprice	1.9312	1.9389
cprice	0.0000	0.0000	cprice	0.0000	0.0000	cprice	1.9312	0.0000
quantity	2.2943	1.4226	quantity	2.2943	1.4226	quantity	1.2540	2.0932
profits	4.4483	2.7581	profits	5.1563	2.7581	profits	2.4218	4.0584
subsidies	7.2064		subsidies	7.9144		subsidies	4.0584	
cs	9.3355		cs	9.3355		cs	5.0446	
ts	9.3355		ts	9.3355		ts	7.4664	
			pbar	3.4215				
			tcrit	0.0000				
lambda	1.0000	0.5000	eta	1.0000	1.0000	cost	1.0000	0.0000
REFERENCE PRICING			**JZ VARIANT**			**NO SUBSIDISATION OF SECOND DRUG**		
pprice	1.9389	1.9389	pprice	2.3071	1.9389	pprice	2.9459	1.9389
cprice	0.0000	0.0000	cprice	0.0000	0.0000	cprice	2.9459	0.0000
quantity	2.2943	1.4226	quantity	2.2010	1.4636	quantity	0.6995	2.2855
profits	2.1540	2.7581	profits	2.9083	2.8377	profits	1.3612	4.4313
subsidies	7.2064		subsidies	7.8514		subsidies	4.4313	
cs	9.3355		cs	9.0048		cs	3.5656	
ts	7.0413		ts	6.8039		ts	4.9268	
			pbar	3.4353				
			tcrit	0.2405				
lambda	1.0000	0.5000	eta	1.0000	1.0000	cost	2.0000	0.0000
REFERENCE PRICING			**JZ VARIANT**			**NO SUBSIDISATION OF SECOND DRUG**		
			pprice	2.3297	1.9389	pprice	3.4773	1.9389
NO SUBSIDISATION			cprice	0.0000	0.0000	cprice	3.4773	0.0000
			quantity	2.1012	1.5058	quantity	0.5121	2.1911
			profits	0.7565	2.9196	profits	0.7565	4.2482
			subsidies	7.6855		subsidies	4.2482	
			cs	8.6529		cs	3.0353	
			ts	4.4505		ts	3.7918	
			pbar	3.4773				
			tcrit	0.5000				
			MAXIMUM COST FOR SUBSIDISATION			1.4831		

Difference in efficacy (λ=0.50, η=1.00 previously subsidised)

lambda	1.0000	0.5000	eta	1.0000	1.0000	cost	0.0000	1.0000
REFERENCE PRICING			**JZ VARIANT**			**NO SUBSIDISATION OF SECOND DRUG**		
pprice	2.0053	2.0053	pprice	2.2474	2.0053	pprice	1.9312	2.0053
cprice	0.0000	0.0000	cprice	0.0000	0.0000	cprice	1.9312	0.0000
quantity	2.2943	1.4226	quantity	2.2943	1.4226	quantity	1.2540	2.0932
profits	4.6007	1.4301	profits	5.1563	1.4301	profits	2.4218	2.1043
subsidies	7.4534		subsidies	8.0089		subsidies	4.1974	
cs	9.3355		cs	9.3355		cs	5.0446	
ts	7.9130		ts	7.9130		ts	5.3732	
			pbar	3.4215				
			tcrit	0.0000				
lambda	1.0000	0.5000	eta	1.0000	1.0000	cost	1.0000	1.0000
REFERENCE PRICING			**JZ VARIANT**			**NO SUBSIDISATION OF SECOND DRUG**		
pprice	2.0053	2.0053	pprice	2.3071	2.0053	pprice	2.9459	2.0053
cprice	0.0000	0.0000	cprice	0.0000	0.0000	cprice	2.9459	0.0000
quantity	2.2943	1.4226	quantity	2.2010	1.4636	quantity	0.6995	2.2855
profits	2.3064	1.4301	profits	2.9083	1.4713	profits	1.3612	2.2976
subsidies	7.4534		subsidies	7.9486		subsidies	4.5832	
cs	9.3355		cs	9.0048		cs	3.5656	
ts	5.6187		ts	5.3403		ts	2.6413	
			pbar	3.4353				
			tcrit	0.2405				
lambda	1.0000	0.5000	eta	1.0000	1.0000	cost	2.0000	1.0000
REFERENCE PRICING			**JZ VARIANT**			**NO SUBSIDISATION OF SECOND DRUG**		
			pprice	2.3297	2.0053	pprice	3.4773	2.0053
NO SUBSIDISATION			cprice	0.0000	0.0000	cprice	3.4773	0.0000
			quantity	2.1012	1.5058	quantity	0.5121	2.1911
			profits	0.7565	1.5138	profits	0.7565	2.2027
			subsidies	7.7855		subsidies	4.3938	
			cs	8.6529		cs	3.0353	
			ts	2.9447		ts	1.6007	
			pbar	3.4773				
			tcrit	0.5000				
			MAXIMUM COST FOR SUBSIDISATION			1.5730		

Difference in efficacy (λ=0.50, η=1.00 previously subsidised)

lambda	1.0000	0.5000	eta	1.0000	1.0000	cost	0.0000	2.0000
REFERENCE PRICING			**JZ VARIANT**			**NO SUBSIDISATION OF SECOND DRUG**		
pprice	2.0310	2.0310	pprice	2.2474	2.0310	pprice	1.9312	2.0310
cprice	0.0000	0.0000	cprice	0.0000	0.0000	cprice	1.9312	0.0000
quantity	2.2943	1.4226	quantity	2.2943	1.4226	quantity	1.2540	2.0932
profits	4.6597	0.0441	profits	5.1563	0.0441	profits	2.4218	0.0649
subsidies	7.5489		subsidies	8.0455		subsidies	4.2512	
cs	9.3355		cs	9.3355		cs	5.0446	
ts	6.4904		ts	6.4904		ts	3.2800	33.0000
			pbar	3.4215				
			tcrit	0.0000				
lambda	1.0000	0.5000	eta	1.0000	1.0000	cost	1.0000	2.0000
REFERENCE PRICING			**JZ VARIANT**			**NO SUBSIDISATION OF SECOND DRUG**		
pprice	2.0310	2.0310	pprice	2.3071	2.0310	pprice	2.9459	2.0310
cprice	0.0000	0.0000	cprice	0.0000	0.0000	cprice	2.9459	0.0000
quantity	2.2943	1.4226	quantity	2.2010	1.4636	quantity	0.6995	2.2855
profits	2.3654	0.0441	profits	2.9083	0.0454	profits	1.3612	0.0708
subsidies	7.5489		subsidies	7.9862		subsidies	4.6419	
cs	9.3355		cs	9.0048		cs	3.5656	
ts	4.1961		ts	3.8767		ts	0.3557	
			pbar	3.4353				
			tcrit	0.2405				
lambda	1.0000	0.5000	eta	1.0000	1.0000	cost	2.0000	2.0000
REFERENCE PRICING			**JZ VARIANT**			**NO SUBSIDISATION OF SECOND DRUG**		
			pprice	2.3297	2.0310	pprice	3.4773	2.0310
NO SUBSIDISATION			cprice	0.0000	0.0000	cprice	3.4773	0.0000
			quantity	2.1012	1.5058	quantity	0.5121	2.1911
			profits	0.7565	0.0467	profits	0.7565	0.0679
			subsidies	7.8242		subsidies	4.4501	
			cs	8.6529		cs	3.0353	
			ts	1.4389		ts	-0.5904	
			pbar	3.4773				
			tcrit	0.5000				
			MAXIMUM COST FOR SUBSIDISATION			1.6075		

Difference in risk (λ=1.00, η=5.00 previously subsidised)

lambda	1.0000	1.0000	eta	1.0000	5.0000	cost	0.0000	0.0000
REFERENCE PRICING			**JZ VARIANT**			**NO SUBSIDISATION OF SECOND DRUG**		
pprice	2.2807	3.2412	pprice	1.9448	3.2412	pprice	0.9903	3.2412
cprice	0.0000	0.9605	cprice	0.0000	0.0000	cprice	0.9903	0.0000
quantity	1.4008	3.0709	quantity	0.7483	3.7415	quantity	0.2764	4.2109
profits	3.1948	9.9535	profits	1.4553	12.1267	profits	0.2737	13.6483
subsidies	10.1988		subsidies	13.5820		subsidies	13.6483	
cs	15.5005		cs	18.7630		cs	18.2936	
ts	18.4500		ts	18.7630		ts	18.5673	
			pbar	2.8082				
			tcrit	0.0000				
lambda	1.0000	1.0000	eta	1.0000	5.0000	cost	1.0000	0.0000
REFERENCE PRICING			**JZ VARIANT**			**NO SUBSIDISATION OF SECOND DRUG**		
pprice	2.6954	3.2412	pprice	2.0180	3.2412	pprice	1.9688	3.2412
cprice	0.0000	0.5458	cprice	0.0000	0.0000	cprice	1.9688	0.0000
quantity	1.1348	3.3468	quantity	0.7109	3.7784	quantity	0.1020	4.3824
profits	1.9239	10.8476	profits	0.7255	12.2463	profits	0.0988	14.2040
subsidies	12.0797		subsidies	13.6766		subsidies	14.2040	
cs	16.8304		cs	18.7261		cs	18.1221	
ts	17.5222		ts	18.0152		ts	18.2209	
			pbar	2.8320				
			tcrit	0.2405				
lambda	1.0000	1.0000	eta	1.0000	5.0000	cost	2.0000	0.0000
REFERENCE PRICING			**JZ VARIANT**			**NO SUBSIDISATION OF SECOND DRUG**		
pprice	3.1324	3.2412	pprice	2.0457	3.2412	pprice	2.9044	3.2412
cprice	0.0000	0.1088	cprice	0.0000	0.0000	cprice	2.9044	0.0000
quantity	0.8288	3.6596	quantity	0.6713	3.8175	quantity	0.0378	4.4432
profits	0.9385	11.8615	profits	0.0342 6	12.3731	profits	0.0342	14.4011
subsidies	14.0595		subsidies	13.7380		subsidies	14.4011	
cs	18.3604		cs	18.6870		cs	18.0613	
ts	17.1009		ts	17.3444		ts	18.0955	
			pbar	2.9045				
			tcrit	0.5000				

Difference in risk (λ=1.00, η=5.00 previously subsidised)

lambda	1.0000	1.0000	eta	1.0000	5.0000	cost	0.0000	1.0000
REFERENCE PRICING			**JZ VARIANT**			**NO SUBSIDISATION OF SECOND DRUG**		
pprice	2.2960	3.2667	pprice	1.9448	3.2667	pprice	0.9903	3.2667
cprice	0.0000	0.9708	cprice	0.0000	0.0000	cprice	0.9903	0.0000
quantity	1.4071	3.0643	quantity	0.7483	3.7415	quantity	0.2764	4.2109
profits	3.2307	6.9460	profits	1.4553	8.4809	profits	0.2737	9.5450
subsidies	10.2663		subsidies	13.6776		subsidies	13.7559	
cs	15.4689		cs	18.7630		cs	18.2936	
ts	15.3794		ts	15.0216		ts	14.3564	
			pbar	2.8082				
			tcrit	0.0000				
lambda	1.0000	1.0000	eta	1.0000	5.0000	cost	1.0000	1.0000
REFERENCE PRICING			**JZ VARIANT**			**NO SUBSIDISATION OF SECOND DRUG**		
pprice	2.7101	3.2667	pprice	2.0180	3.2667	pprice	1.9688	3.2667
cprice	0.0000	0.5567	cprice	0.0000	0.0000	cprice	1.9688	0.0000
quantity	1.1421	3.3393	quantity	0.7109	3.7784	quantity	0.1020	4.3824
profits	1.9531	7.5694	profits	0.7255	8.5645	profits	0.0988	9.9337
subsidies	12.1449		subsidies	13.7732		subsidies	14.3161	
cs	16.7940		cs	18.7261		cs	18.1221	
ts	14.1716		ts	14.2368		ts	13.8385	
			pbar	2.8320				
			tcrit	0.2405				
lambda	1.0000	1.0000	eta	1.0000	5.0000	cost	2.0000	1.0000
REFERENCE PRICING			**JZ VARIANT**			**NO SUBSIDISATION OF SECOND DRUG**		
pprice	3.1465	3.2667	pprice	2.0457	3.2667	pprice	2.9044	3.2667
cprice	0.0000	0.1203	cprice	0.0000	0.0000	cprice	2.9044	0.0000
quantity	0.8372	3.6511	quantity	0.6713	3.8175	quantity	0.0378	4.4432
profits	0.9598	8.2762	profits	0.0342 6	8.65322	profits	0.0342	10.0715
subsidies	14.1224		subsidies	13.8356		subsidies	14.5147	
cs	18.3185		cs	18.6870		cs	18.0613	
ts	13.4321		ts	13.5269		ts	13.6523	
			pbar	2.9045				
			tcrit	0.5000				

Difference in risk (λ=1.00, η=5.00 previously subsidised)

lambda	1.0000	1.0000	eta	1.0000	5.0000	cost	0.0000	2.0000
REFERENCE PRICING			**JZ VARIANT**			**NO SUBSIDISATION OF SECOND DRUG**		
pprice	2.3019	3.2766	pprice	1.9448	3.2766	pprice	0.9903	3.2766
cprice	0.0000	0.9747	cprice	0.0000	0.0000	cprice	0.9903	0.0000
quantity	1.4096	3.0618	quantity	0.7483	3.7415	quantity	0.2764	4.2109
profits	3.2446	3.9087	profits	1.4553	4.7764	profits	0.2737	5.3757
subsidies	10.2924		subsidies	13.7145		subsidies	13.7975	
cs	15.4567		cs	18.7630		cs	18.2936	
ts	12.3176		ts	11.2801		ts	10.1455	
			pbar	2.8082				
			tcrit	0.0000				
lambda	1.0000	1.0000	eta	1.0000	5.0000	cost	1.0000	2.0000
REFERENCE PRICING			**JZ VARIANT**			**NO SUBSIDISATION OF SECOND DRUG**		
pprice	2.7157	3.2766	pprice	2.0180	3.2766	pprice	1.9688	3.2766
cprice	0.0000	0.5609	cprice	0.0000	0.0000	cprice	1.9688	0.0000
quantity	1.1029	3.3786	quantity	0.7109	3.7784	quantity	0.1020	4.3824
profits	1.8891	4.3132	profits	0.7255	4.8235	profits	0.0988	5.5946
subsidies	12.2584		subsidies	13.8105		subsidies	14.3593	
cs	16.8341		cs	18.7261		cs	18.1221	
ts	10.7780		ts	10.4585		ts	9.4562	
			pbar	2.8320				
			tcrit	0.2405				
lambda	1.0000	1.0000	eta	1.0000	5.0000	cost	2.0000	2.0000
REFERENCE PRICING			**JZ VARIANT**			**NO SUBSIDISATION OF SECOND DRUG**		
pprice	3.1519	3.2766	pprice	2.0457	3.2766	pprice	2.9044	3.2766
cprice	0.0000	0.1247	cprice	0.0000	0.0000	cprice	2.9044	0.0000
quantity	0.8404	3.6479	quantity	0.6713	3.8175	quantity	0.0378	4.4432
profits	0.9681	4.6569	profits	0.0342 6	4.87342	profits	0.0342	5.6722
subsidies	14.1467		subsidies	13.8733		subsidies	14.5586	
cs	18.3024		cs	18.6870		cs	18.0613	
ts	9.7807		ts	9.7094		ts	9.2090	
			pbar	2.9045				
			tcrit	0.5000				

Difference in risk (λ=1.00, η=1.00 previously subsidised)

lambda	1.0000	1.0000	eta	5.0000	1.0000	cost	0.0000	0.0000
REFERENCE PRICING			**JZ VARIANT**			**NO SUBSIDISATION OF SECOND DRUG**		
pprice	2.5532	1.8756	pprice	2.5765	2.5532	pprice	3.0498	2.5532
cprice	0.6776	0.0000	cprice	0.0000	0.0000	cprice	3.0498	0.0000
quantity	3.2571	1.2218	quantity	3.7415	0.7483	quantity	1.8418	2.4236
profits	8.3161	2.2917	profits	9.6398	1.9106	profits	5.6171	6.1880
subsidies	8.4009		subsidies	11.5503		subsidies	6.1880	
cs	16.3953		cs	18.7630		cs	10.3865	
ts	18.6022		ts	18.7630		ts	16.0036	
			pbar	3.7427				
			tcrit	0.0000				
lambda	1.0000	1.0000	eta	5.0000	1.0000	cost	1.0000	0.0000
REFERENCE PRICING			**JZ VARIANT**			**NO SUBSIDISATION OF SECOND DRUG**		
pprice	2.5532	1.8756	pprice	2.6254	2.5532	pprice	3.4225	2.5532
cprice	0.6776	0.0000	cprice	0.0000	0.0000	cprice	3.4225	0.0000
quantity	3.2571	1.2218	quantity	3.6165	0.8487	quantity	1.6067	2.5523
profits	5.0590	2.2917	profits	5.9602	2.1670	profits	3.8923	6.5165
subsidies	8.4009		subsidies	11.4714		subsidies	6.5165	
cs	16.3953		cs	18.2609		cs	9.7432	
ts	15.3451		ts	14.6444		ts	13.6355	
			pbar	3.7520				
			tcrit	0.2405				
lambda	1.0000	1.0000	eta	5.0000	1.0000	cost	2.0000	0.0000
REFERENCE PRICING			**JZ VARIANT**			**NO SUBSIDISATION OF SECOND DRUG**		
			pprice	2.6441	2.5532	pprice	3.7808	2.5532
NO SUBSIDISATION			cprice	0.0000	0.0000	cprice	3.7808	0.0000
			quantity	3.4827	0.9553	quantity	1.3532	2.6585
			profits	2.4097	2.4390	profits	2.4097	6.7878
			subsidies	11.2597		subsidies	6.7878	
			cs	17.7281		cs	9.2119	
			ts	10.7628		ts	11.6216	
			pbar	3.7808				

Difference in risk (λ=1.00, η=1.00 previously subsidised)

lambda	1.0000	1.0000	eta	5.0000	1.0000	cost	0.0000	1.0000
REFERENCE PRICING			**JZ VARIANT**			**NO SUBSIDISATION OF SECOND DRUG**		
pprice	2.6002	2.3319	pprice	2.5765	2.6002	pprice	3.0498	2.6002
cprice	0.2683	0.0000	cprice	0.0000	0.0000	cprice	3.0498	0.0000
quantity	3.5426	0.9437	quantity	3.7415	0.7483	quantity	1.8418	2.4236
profits	9.2115	1.2569	profits	9.6398	1.1974	profits	5.6171	3.8782
subsidies	10.4616		subsidies	11.5855		subsidies	6.3018	
cs	17.7861		cs	18.7630		cs	10.3865	
ts	17.7929		ts	18.0147		ts	13.5800	
			pbar	3.7427				
			tcrit	0.0000				
lambda	1.0000	1.0000	eta	5.0000	1.0000	cost	1.0000	1.0000
REFERENCE PRICING			**JZ VARIANT**			**NO SUBSIDISATION OF SECOND DRUG**		
pprice	2.6002	2.3319	pprice	2.6254	2.6002	pprice	3.4225	2.6002
cprice	0.2683	0.0000	cprice	0.0000	0.0000	cprice	3.4225	0.0000
quantity	3.5426	0.9437	quantity	3.6165	0.8487	quantity	1.6067	2.5523
profits	5.6689	1.2569	profits	5.9602	1.3581	profits	3.8923	4.0841
subsidies	10.4616		subsidies	11.5112		subsidies	6.6364	
cs	17.7861		cs	18.2609		cs	9.7432	
ts	14.2503		ts	13.7956		ts	11.0833	
			pbar	3.7520				
			tcrit	0.2405				
lambda	1.0000	1.0000	eta	5.0000	1.0000	cost	2.0000	1.0000
REFERENCE PRICING			**JZ VARIANT**			**NO SUBSIDISATION OF SECOND DRUG**		
			pprice	2.6441	2.6002	pprice	3.7808	2.6002
NO SUBSIDISATION			cprice	0.0000	0.0000	cprice	3.7808	0.0000
			quantity	3.4827	0.9553	quantity	1.3532	2.6585
			profits	2.4097	1.5286	profits	2.4097	4.2541
			subsidies	11.3046		subsidies	6.9127	
			cs	17.7281		cs	9.2119	
			ts	9.8075		ts	8.9631	
			pbar	3.7808				
			tcrit	0.5000				

Difference in risk (λ=1.00, η=1.00 previously subsidised)

lambda	1.0000	1.0000	eta	5.0000	1.0000	cost	0.0000	2.0000
REFERENCE PRICING			**JZ VARIANT**			**NO SUBSIDISATION OF SECOND DRUG**		
pprice	2.6182	2.6182	pprice	2.5765	2.6182	pprice	3.0498	2.6182
cprice	0.0000	0.0000	cprice	0.0000	0.0000	cprice	3.0498	0.0000
quantity	3.7415	0.7483	quantity	3.7415	0.7483	quantity	1.8418	2.4236
profits	9.7957	0.4626	profits	9.6398	0.4626	profits	5.6171	1.4982
subsidies	11.7549		subsidies	11.5989		subsidies	6.3454	
cs	18.7630		cs	18.7630		cs	10.3865	
ts	17.2664		ts	17.2665		ts	11.1564	
			pbar	3.7427				
			tcrit	0.0000				
lambda	1.0000	1.0000	eta	5.0000	1.0000	cost	1.0000	2.0000
REFERENCE PRICING			**JZ VARIANT**			**NO SUBSIDISATION OF SECOND DRUG**		
pprice	2.6182	2.6182	pprice	2.6254	2.6182	pprice	3.4225	2.6182
cprice	0.0000	0.0000	cprice	0.0000	0.0000	cprice	3.4225	0.0000
quantity	3.7415	0.7483	quantity	3.6165	0.8487	quantity	1.6067	2.5523
profits	6.0543	0.4626	profits	5.9602	0.5247	profits	3.8923	1.5777
subsidies	11.7549		subsidies	11.5265		subsidies	6.6822	
cs	18.7630		cs	18.2609		cs	9.7432	
ts	13.5249		ts	12.9469		ts	8.5310	
			pbar	3.7520				
			tcrit	0.2405				
lambda	1.0000	1.0000	eta	5.0000	1.0000	cost	2.0000	2.0000
REFERENCE PRICING			**JZ VARIANT**			**NO SUBSIDISATION OF SECOND DRUG**		
			pprice	2.6441	2.6182	pprice	3.7808	2.6182
NO SUBSIDISATION			cprice	0.0000	0.0000	cprice	3.7808	0.0000
			quantity	3.4827	0.9553	quantity	1.3532	2.6585
			profits	2.4097	0.5905	profits	2.4097	1.6434
			subsidies	11.3217		subsidies	6.9604	
			cs	17.7281		cs	9.2119	
			ts	8.8522		ts	6.3046	
			pbar	3.7808				
			tcrit	0.5000				

Appendix 10.2 Sensitivity analysis.

The following tables contain the full results of the sensitivity analysis for the comparisons referred to in Chapter 10. The legend below gives the names and quantities for each figure displayed on the following tables.

name	explanation
pprice	equilibrium producer price
cprice	equilibrium consumer price
quantity	quantity over full period to generic entry
profits	profits over full period to generic entry
subsidies	subsidies required over full period to generic entry
cs	consumer surplus over full period to generic entry
ts	total surplus over full period to generic entry
pbar	for JZ scheme only: price charged by entrant pre-subsidisation
tcrit	for JZ scheme only: time elapsed when subsidisation accepted

Fixed Charge

lambda	1	1	eta	1	1	cost	1	1

k = 0.00

REFERENCE PRICING

pprice	2.6002	2.6002
cprice	0	0
quantity	1.94588	1.94588
profits	3.1138	3.1138
subsidies	10.1194	
cs	12.7751	
ts	8.8833	

JOHNSTON-ZECKHAUSER VARIANT

pprice	2.3673	2.6002
cprice	0	0
quantity	1.87096	1.98904
profits	2.58782	3.18286
subsidies	9.53516	
cs	12.5593	
ts	8.69928	
pbar	3.43527	
tcrit	0.240488	

NO SUBSIDISATION OF SECOND DRUG

pprice	2.94587	2.6002
cprice	2.94587	0
quantity	0.699537	2.7034
profits	1.36121	4.32598
subsidies	7.02938	
cs	8.98747	
ts	5.58453	

k = 0.50

REFERENCE PRICING

pprice	2.6412	2.6412
cprice	0.5	0.5
quantity	1.87845	1.87845
profits	3.08296	3.08296
subsidies	8.04437	
cs	10.8618	
ts	~~7.10487~~ 8.98335	

JOHNSTON-ZECKHAUSER VARIANT

pprice	2.4247	2.6412
cprice	0.5	0.5
quantity	1.81001	1.91552
profits	2.60975	3.1438
subsidies	7.52612	
cs	10.6764	
ts	~~6.95089~~ 8.9038	
pbar	3.43527	
tcrit	0.240488	

NO SUBSIDISATION OF SECOND DRUG

pprice	2.94587	2.6412
cprice	2.94587	0.5
qnty	0.773107	2.51436
profits	1.50437	4.12663
subsidies	5.3838	
cs	7.68224	
ts	~~5.39427~~ 7.92944	

Time to generic entry

lambda	1	1	eta	1	1	cost	1	1

T = 5.98

REFERENCE PRICING		
pprice	2.6002	2.6002
cprice	0	0
quantity	1.94588	1.94588
profits	3.1138	3.1138
subsidies	10.1194	
cs	12.7751	
ts	8.8833	

JOHNSTON-ZECKHAUSER VARIANT		
pprice	2.3673	2.6002
cprice	0	0
quantity	1.87096	1.98904
profits	2.58782	3.18286
subsidies	9.53516	
cs	12.5593	
ts	8.69928	
pbar	3.43527	
tcrit	0.240488	

NO SUBSIDISATION OF SECOND DRUG		
pprice	2.94587	2.6002
cprice	2.94587	0
quantity	0.699537	2.7034
profits	1.36121	4.32598
subsidies	7.02938	
cs	8.98747	
ts	5.58453	

T = 8.00

REFERENCE PRICING		
pprice	2.6037	2.6037
cprice	0	0
quantity	2.38073	2.38073
profits	3.81791	3.81791
subsidies	12.3973	
cs	15.6299	
ts	10.8684	

JOHNSTON-ZECKHAUSER VARIANT		
pprice	2.3714	2.6037
cprice	0	0
quantity	2.30532	2.42413
profits	3.19137	3.8875
subsidies	11.7126	
cs	15.4129	
ts	10.6835	
pbar	3.44288	
tcrit	0.241596	

NO SUBSIDISATION OF SECOND DRUG		
pprice	2.94587	2.6037
cprice	2.94587	0
qnty	0.855862	3.30753
profits	1.6654	5.30419
subsidies	8.61172	
cs	10.9959	
ts	6.8325	

Subsidisation threshold

lambda	1	1	eta	1	1	cost	1	1

t_{max} = 0.50

REFERENCE PRICING			JOHNSTON-ZECKHAUSER VARIANT			NO SUBSIDISATION OF SECOND DRUG		
pprice	2.6002	2.6002	pprice	2.3673	2.6002	pprice	2.94587	2.6002
cprice	0	0	cprice	0	0	cprice	2.94587	0
quantity	1.94588	1.94588	quantity	1.87096	1.98904	quantity	0.699537	2.7034
profits	3.1138	3.1138	profits	2.58782	3.18286	profits	1.36121	4.32598
subsidies	10.1194		subsidies	9.53516		subsidies	7.02938	
cs	12.7751		cs	12.5593		cs	8.98747	
ts	8.8833		ts	8.69928		ts	5.58453	
			pbar	3.43527				
			tcrit	0.240488				

t_{max} = 0.25

REFERENCE PRICING			JOHNSTON-ZECKHAUSER VARIANT			NO SUBSIDISATION OF SECOND DRUG		
pprice	2.6094	2.6094	pprice	2.3783	2.6094	pprice	2.94587	2.6094
cprice	0	0	cprice	0	0	cprice	2.94587	0
quantity	1.94588	1.94588	quantity	1.90728	1.96806	quantity	0.699537	2.7034
profits	3.13169	3.13169	profits	2.6439	3.16738	profits	1.36121	4.35083
subsidies	10.1551		subsidies	9.63805		subsidies	7.05423	
cs	12.7751		cs	12.6642		cs	8.98747	
ts	8.8833		ts	8.78881		ts	5.58453	
			pbar	3.45591				
			tcrit	0.122553				

t_{max} = 1.00

REFERENCE PRICING			JOHNSTON-ZECKHAUSER VARIANT			NO SUBSIDISATION OF SECOND DRUG		
pprice	2.5808	2.5808	pprice	2.3441	2.5808	pprice	2.94587	2.5808
cprice	0	0	cprice	0	0	cprice	2.94587	0
quantity	1.94588	1.94588	quantity	1.80425	2.02783	quantity	0.699537	2.7034
profits	3.07598	3.07598	profits	2.48228	3.20553	profits	1.36121	4.27344
subsidies	10.0437		subsidies	9.33501		subsidies	6.97685	
cs	12.7751		cs	12.3653		cs	8.98747	
ts	8.8833		ts	8.53322		ts	5.58453	
			pbar	3.39606				
			tcrit	0.464134				

Appendix 10.3 Reference pricing / JZ variant switch point

The following pages give the outcomes of the nine standard cases under reference pricing and the JZ variant for the case where $\lambda_1 = 0.62, \lambda_2 = 1.000, \eta_1 = \eta_2 = 1$. In this scenario the average change in total surplus when shifting between the two schemes is less than 0.005.

JZ VARIANT

lambda	0.62	1

eta	1	1

c1 = 0, c2 = 0

pprice	2.004	2.5532
cprice	0	0
quantity	1.5992	2.1708
profits	3.20473	5.54252
subsidies	8.74726	
cs - subsidy	9.92178	
ts - subsidy	9.92178	
pbar	2.49528	
tcrit	0.	

c1 = 0, c2 = 1

pprice	2.004	2.6002
cprice	0	0
quantity	1.5992	2.1708
profits	3.20473	3.47371
subsidies	8.84925	
cs - subsidy	9.92178	
ts - subsidy	7.75098	
pbar	2.49528	
tcrit	0.	

c1 = 0, c2 = 2

pprice	2.004	2.6182
cprice	0	0
quantity	1.5992	2.1708
profits	3.20473	1.34191
subsidies	8.88825	
cs - subsidy	9.92178	
ts - subsidy	5.58018	
pbar	2.49528	
tcrit	0.	

c1 = 1, c2 = 0

pprice	2.0675	2.5532
cprice	0	0
quantity	1.52993	2.20251
profits	1.63982	5.62348
subsidies	8.75521	
cs - subsidy	9.83811	
ts - subsidy	8.30817	
pbar	2.50847	
tcrit	0.240488	

c1 = 1, c2 = 1

pprice	2.0675	2.6002
cprice	0	0
quantity	1.52993	2.20251
profits	1.63982	3.52445
subsidies	8.85869	
cs - subsidy	9.83811	
ts - subsidy	6.10566	
pbar	2.50847	
tcrit	0.240488	

c1 = 1, c2 = 2

pprice	2.0675	2.6182
cprice	0	0
quantity	1.52993	2.20251
profits	1.63982	1.36151
subsidies	8.89826	
cs - subsidy	9.83811	
ts - subsidy	3.90315	
pbar	2.50847	
tcrit	0.240488	

c1 = 2, c2 = 0

pprice	2.0918	2.5532
cprice	0	0
quantity	1.45489	2.23651
profits	0.146781	5.7103
subsidies	8.69301	
cs - subsidy	9.74922	
ts - subsidy	6.83943	
pbar	2.54889	
tcrit	0.5	

c1 = 2, c2 = 1

pprice	2.0918	2.6002
cprice	0	0
quantity	1.45489	2.23651
profits	0.146781	3.57886
subsidies	8.79809	
cs - subsidy	9.74922	
ts - subsidy	4.60292	
pbar	2.54889	
tcrit	0.5	

c1 = 2, c2 = 2

pprice	2.0918	2.6182
cprice	0	0
quantity	1.45489	2.23651
profits	0.146781	1.38253
subsidies	8.83827	
cs - subsidy	9.74922	
ts - subsidy	2.3664	
pbar	2.54889	
tcrit	0.5	

REFERENCE PRICING

lambda	0.62	1	eta	1	1			
c1 = 0, c2 = 0			c1 = 0, c2 = 1			c1 = 0, c2 = 2		
pprice	2.5532	2.5532	pprice	2.6002	2.6002	pprice	2.6182	2.6182
cprice	0	0	cprice	0	0	cprice	0	0
quantity	1.5992	2.1708	quantity	1.5992	2.1708	quantity	1.5992	2.1708
profits	4.08311	5.54252	profits	4.15825	3.47371	profits	4.18698	1.34191
subsidies	9.62564		subsidies	9.80276		subsidies	9.87049	
cs - subsidy	9.92178		cs - subsidy	9.92178		cs - subsidy	9.92178	
ts - subsidy	9.92178		ts - subsidy	7.75098		ts - subsidy	5.58018	
c1 = 1, c2 = 0			c1 = 1, c2 = 1			c1 = 1, c2 = 2		
pprice	2.5532	2.5532	pprice	2.6002	2.6002	pprice	2.6182	2.6182
cprice	0	0	cprice	0	0	cprice	0	0
quantity	1.5992	2.1708	quantity	1.5992	2.1708	quantity	1.5992	2.1708
profits	2.48391	5.54252	profits	2.55904	3.47371	profits	2.58777	1.34191
subsidies	9.62564		subsidies	9.80276		subsidies	9.87049	
cs - subsidy	9.92178		cs - subsidy	9.92178		cs - subsidy	9.92178	
ts - subsidy	8.32257		ts - subsidy	6.15177		ts - subsidy	3.98097	
c1 = 2, c2 = 0			c1 = 2, c2 = 1			c1 = 2, c2 = 2		
pprice	2.5532	2.5532	pprice	2.6002	2.6002	pprice	2.6182	2.6182
cprice	0	0	cprice	0	0	cprice	0	0
quantity	1.5992	2.1708	quantity	1.5992	2.1708	quantity	1.5992	2.1708
profits	0.884704	5.54252	profits	0.959839	3.47371	profits	0.98857	1.34191
subsidies	9.62564		subsidies	9.80276		subsidies	9.87049	
cs - subsidy	9.92178		cs - subsidy	9.92178		cs - subsidy	9.92178	
ts - subsidy	6.72337		ts - subsidy	4.55257		ts - subsidy	2.38177	